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Effect of Sub-Lethal Doses of Toxicants on Susceptibility of Insects to Insecticides

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A knowledge of the susceptibility to insecticides of insects which have survived one insecticidal treatment might shed some light on the phenomenon of resistance to insecticides, on the question of joint action of insecticides, and on practical control operations involving repeated applications of insecticides.

Observations contributing to this knowledge are rather scattered and have been made from different points of view. Quayle (1922) found that individuals of the citrus red scale surviving one fumigation with hydrocyanic acid were more resistant to a second fumigation than individuals not previously treated. Gray & Kirkpatrick (1929) presented evidence for this phenomenon, which they termed "protective stupefaction," in both the red and black citrus scale. On the other hand, Moore (1933) found that exposure of the citrus red scale to low concentrations of hydrocyanic acid before fumigation might reduce the kill in some cases, but in other cases the pretreatment had no effect or even increased the final kill. Campbell (1926) found that individual silkworms, receiving a number of sublethal doses of neutral sodium arsenate solution administered by mouth during their larval development, did not acquire a tolerance for arsenic. Moreover the early sublethal doses were apparently eliminated as there was little evidence of cumulative action. Conditions resembling "protective stupefaction" were reported by McGovran *et al.* (1939) who noted a temporary resistance to pyrethrins in houseflies that had received a knock-down dose of ether, acetone, or kerosene-pyrethrin spray before being exposed to a higher killing dose of pyrethrins, and by Kono (1949) who reported that prefumigation of the rice weevil with low doses of carbon disulfide decreased susceptibility to this chemical. Lindquist *et al.* (1947) observed that certain pyrethrum synergists were still effective as synergists if they were administered separately from pyrethrum in point of time, provided the synergists preceded the pyrethrum. In other words, house flies pretreated with the synergists were more susceptible to pyrethrum than flies not so pretreated. Hoffman *et al.* (1951) reported that house flies surviving six exposures during a 3-day period to surfaces treated with DDT were killed much more easily than unexposed flies when subsequently exposed to a higher dosage of DDT, suggesting that DDT or a toxic by-product accumulated in the flies. Turner (1951) presented data indicating that milkweed bugs pretreated with nicotine were somewhat more susceptible to pyrethrum than bugs not pretreated, whereas bugs pretreated with pyrethrum were somewhat less susceptible to nicotine than bugs not pretreated.

At the outset it might appear that techniques for studying susceptibility to insecticides as modified by pretreatment would be simple and straightforward. In practice, however, they are not, perhaps chiefly (1) because group response must be used as a criterion for the sum of the individual responses which are extremely variable, (2) because, for purely practical reasons, large populations cannot be tested easily, and (3) because difficulties are encountered in distinguishing between effects of the initial treatment and the final treatment. In view of these considerations it is possible that some of the observations reported above would be subject to different interpretations if more information were available.

In the present study, after several experimental designs were tried and dis-

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carded, emphasis was placed on the injection of insects, in a laboratory population, with a single concentration of a given toxicant and a week later re-treating the survivors with a dosage-series of the same or different toxicant, comparing the response with that of a similar population not having received the initial chemical treatment. Four insecticides—nicotine, DDT, pyrethrum, and arsenic—were used on two insects—larvae of the wax moth, *Galleria mellonella* (L.), and adults of the large milkweed bug, *Oncopeltus fasciatus* (Dall.). The nicotine was in the form of the free base dissolved in water. The DDT was pure p,p′ DDT dissolved in olive oil. The pyrethrum was in a 20 per cent extract dissolved in olive oil. Arsenic was in the form of sodium metarsenite, dissolved in water. In all treatments, each insect received approximately 1 microliter of the test solution by injection—into the body cavity in the case of the milkweed bug, and into the esophagus in the case of the wax moth larvae. At the time of the initial treatment the control insects were injected with distilled water to parallel the nicotine- or arsenic-injected insects, or with olive oil to parallel the DDT- or pyrethrum-injected insects. Tests in which there was appreciable mortality among the check insects were discarded.

An effort was made to use the LD_{50} for the initial treatment (Beard 1949 a) but, as is well known, biological variation is such that the LD_{50}, calculated from a series of tests, does not necessarily kill just 50 per cent in all test populations. More will be said below about the degree of selective pressure (severity of initial treatment) and its effect on the response to the secondary treatment, but in this series of tests, out of the 80 tests considered, in 67 the response to the initial treatment was between the 30 per cent and the 70 per cent levels.

Evaluations of the initial treatment were made 1 week later, just prior to the administration of the second treatment. Evaluations of the secondary treatment and of other tests reported below were made three days after treatment. The criteria used for evaluations were on the basis of the following scoring system:

0-insect apparently unaffected by test chemical
1-insect visibly affected by test chemical, but not to the point of preventing its reaching food and water, if required
2-insect incapacitated, but showing some activity
3-insect dead beyond question

A maximum score would be $3n$, where n is the number of test insects, and the test score was calculated in terms of percentage of this maximum. This scoring system has the advantage over mortality alone in that it takes into account some of the sublethal effects of the chemical, and also the time of evaluation after testing is less critical chiefly because the scoring anticipates the end result (Beard 1949 b). This is because those scored 1 tend to recover, and those scored 2 tend to die.

If the initial treatment had no effect on the response to the second treatment, and if the survivors did truly represent the more resistant individuals of the original population, a more homogeneous population, less susceptible to the toxicant than the control population, should be evident. The results, however, show neither a more homogenous population nor a more resistant group. The results[1] of the tests on *Oncopeltus* adults are summarized in table 1, with the susceptibility of the chemically-selected bugs expressed in terms of the non-selected population. In almost all cases, the selected populations and the control populations were equally susceptible. The exceptions are that bugs surviving DDT were more susceptible than the controls to nicotine and DDT, and bugs surviving pyrethrum

Table 1.—Susceptibility of *Oncopeltus* adults receiving primary treatment compared with bugs not receiving primary treatment.

Primary Treatment	Secondary Treatment			
	Nicotine	DDT	Pyrethrum	Arsenic
Nicotine	*	*	*	*
DDT	>	>	*	*
Pyrethrum	*	*	<?	*
Arsenic	*	*	*	*

* Susceptibility of chemically-selected insects equal to that of the non-selected insects.
>(<) Susceptibility of chemically-selected insects greater than (less than) that of the non-selected insects.

[1] The results are based on two or more tests conducted similarly, but at different times. In each test an attempt was made to apply the initial treatment to sufficient insects to provide 100 or more survivors, free from obvious toxic symptoms, for the second treatment. Excessive mortality, either among the chemically-treated insects or the solvent-treated insects, and in the case of *Galleria* larvae, excessive pupation occasionally reduced this number. In the secondary treatment, from 15 to 20 individuals were usually used for each dosage, five dosages being administered. It did not appear that refined statistical analysis of all the data would yield much information not apparent by inspection of the curves plotted on logarithmic-probability paper, but where applicable, the rapid approximate statistical procedures of Wilcoxon (1949) were used.

Table 2.—Susceptibility of *Galleria* larvae receiving primary treatment compared with larvae not receiving primary greatment.

Primary Treatment	Secondary Treatment			
	Nicotine	DDT	Pyrethrum	Arsenic
Nicotine	>	=	*	*
DDT	>	>	>	>
Pyrethrum	>	>	>	>
Arsenic	=	>	>	*

were possibly less susceptible to pyrethrum, but this difference barely reaches the 5 per cent level of significance.

On the same basis, the data for *Galleria* larvae are given in table 2. These data indicate that in most of the tests, the chemically-selected larvae were more susceptible to the second treatment than were the larvae of the control population, and in no case were they less susceptible. This conclusion requires modification, because it was observed that the larvae while under the influence of the first treatment did not grow so rapidly as did the control larvae. Consequently, if at the time of the second treatment the dose per unit body weight is considered, the selected larvae actually received a higher dose of the toxicant than did the control larvae. If then, the dosage is calculated on the basis of the body weight of the larvae, a somewhat different picture is seen as in table 3. But even with this adjustment, in no case does the chemically-selected population appear to be more resistant than the control population.

Table 3.—Susceptibility of *Galleria* larvae receiving primary treatment compared with larvae not receiving primary treatment

(Dosage on basis of body weight)

Primary Treatment	Secondary Treatment			
	Nicotine	DDT	Pyrethrum	Arsenic
Nicotine	=	=	=	>?
DDT	=	>	>	>
Pyrethrum	=	=	>	=
Arsenic	=	=	>	=

Another consideration is the degree of selective pressure exerted by the initial injection. As was mentioned in the above tests, the LD_{50} was the dose usually used in the primary treatment. In another series of tests, four doses of pyrethrum were injected into four large groups of milkweed bugs, resulting in mortalities[2] of 8, 52, 79, and 93 per cent. The surviving populations, namely, the 92, 48, 21, and 7 per cent in terms of the original populations, were injected with a dosage series of nicotine, and their responses were compared with populations similarly treated with nicotine, but not receiving the original pyrethrum. In all four comparisons, the bugs surviving the pyrethrum treatment were equal to non-selected bugs in their susceptibility to nicotine. Consequently, for this particular combination of toxicants, the degree of selective pressure was unimportant in terms of response to the secondary treatment.

In none of the above tests was the slope of the dosage-response curve of the selected populations steeper than that of the unselected insects. In other words, there was no less variation among the individuals surviving one treatment than among those exposed to the chemical for the first time. In fact, in a few of the tests, the slope was flatter for the selected populations, indicating a less homogeneous group.

Clearly then, if we are dealing with the more resistant individuals of the original population, this fact is obscured by the carry-over effect of the primary treatment. To consider this possibility further, one group of each insect was treated with a dose of each of the four insecticides. Other groups were treated twice with one-half of this dose each time, and with various intervals between treatment. The second treatment was made on the first, second, or fourth day after the first. In other words, four groups received the same total dosage, but three of the groups received this in two portions, spaced with different time intervals. With this experimental design, one would expect additive effects to be indicated by equal responses in all groups receiving the same total dose. Elimination or detoxification should be indicated by reduced mortality with increase in the time interval between administrations. Sensitization should be indicated by excessive mortality resulting from the second injection.

The results of this test on *Oncopeltus* are expressed in table 4 in per cent mortality, representing the average of three replicates.

[2] Corrected for natural mortality by Abbott's formula.

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Table 4.—Mortality of *Oncopeltus* adults resulting from administration of toxicants in single and double dosage units with different times intervening.

	x	2x	xx	x-x	x—x
Nicotine (%)	25	33	37	22	44
DDT (%)	83	91	96	95	87
Pyrethrum (%)	56	94	98	89	85
Arsenic (%)	42	90	52	49	32

x=unit dose.
2x=two unit doses applied at one time.
xx=two unit doses applied on successive days.
x-x=two unit doses applied with one day intervening.
x—x=two unit doses applied with three days intervening.

These results indicate that the dosages of nicotine were additive, although the responses were variable. Sensitization is suggested as a possibility with DDT and pyrethrum when the doses were administered on successive days, but some elimination is suggested after several days, particularly with pyrethrum. The variation among replicates is great enough, however, to indicate that the DDT elimination is not significant. Arsenic, however, is definitely eliminated or detoxified, as the mortality is consistently reduced as the time between administrations is increased. In fact, the low figure for those bugs treated four days apart even suggests some induction of tolerance.

The data for *Galleria* larvae, shown in table 5, point to similar conclusions except that nicotine as well as arsenic appears to be eliminated or detoxified, but tolerance is not induced.

Table 5.—Mortality of *Galleria* larvae resulting from administration of toxicants in single and double dosage units with different times intervening.

	x	2x	xx	x-x	x—x
Nicotine (%)	25	56	33	32	34
DDT (%)	23	43	76	70	53
Pyrethrum (%)	24	68	76	78	60
Arsenic (%)	23	86	19	32	24

A conflict becomes apparent in the data derived from the two techniques discussed above. The one technique clearly demonstrates that arsenic is eliminated by both insects, that nicotine appears to be eliminated by *Galleria* larva, and there is some suggestion that pyrethrum, and to a lesser extent, DDT, are eliminated after a longer period of time. On the other hand, the insects surviving one treatment, when given a second treatment in a dosage series one week later respond essentially in the same way as insects not receiving the primary treatment. There are no well-defined differences among chemicals or combinations of chemicals in this respect. One certainly would expect to note a change in group response when arsenic is administered in the primary treatment, as this is so obviously eliminated or detoxified by insects surviving the selective dose, in so far as can be judged by the technique employed. It must be concluded then that the techniques are not measuring the responses it is thought they are measuring, or the test populations are not responding in the manner in which it is thought they should respond. The latter seems the more likely in view of the facts that no well-defined differences are demonstrated between selected and unselected insect groups, regardless of chemicals (except where carry-over (additive dosage) effects are apparent) and that in the one series of tests made, the degree of selective pressure was unimportant.

After exposure to chemicals killing a portion of the population, the surviving individuals seem to regroup themselves into a distribution of susceptibilities, as measured by the dosage-response curve, which is essentially the same as the original population, or at least no more homogeneous nor more resistant. This would imply a relative stability of the group response, but an instability of the individual response. It indicates that some individuals resistant to one treatment are susceptible to a second, but not necessarily in accordance with additive effects. It becomes important to know if the variation among individuals in a group is static or dynamic. In other words, does an individual always occupy the same position of susceptibility relative to the rest of the population of which it is a member, or do the individuals shift their relative positions at different times? This cannot be tested if mortality is the criterion of response, for the dead cannot be brought to life for a second test. But it can be tested using stupefacients and recovery time. Broadbent & Bliss (1936) used this technique and concluded from group response that the variation was presumably static, but they did not note the individual responses in terms of the individual. This concept was tested by exposing groups of insects to non-lethal

paralysants, noting recovery time of identified individuals. This was repeated to see if the sequence of recovery was the same, that is, if those individuals recovering rapidly would consistently be the first to recover and if those recovering slowly would consistently be the last to recover. Tests with *Oncopeltus* adults, *Galleria* larva, and *Habrobracon* (=*Microbracon*) adults, using carbon dioxide, nicotine, and cyanide, all showed the same thing—namely, that the sequence was different in every test. As a typical example of the data obtained, figure 1 illustrates the sequence of recovery of *Oncopeltus* adults, each injected with approximately one microliter of a 0.05 per cent aqueous solution of nicotine on each of three successive days. This dosage paralyzed most of the bugs for periods of from a few minutes to a few hours, but permitted almost complete recovery. Although three individuals (not illustrated in the figure) were not paralyzed by any of the three injections, others not paralyzed in one test or another, were not necessarily the first ones to recover when they were paralyzed in the other tests. And it will be noted that the two individuals which died during the test period were not necessarily those which were slow to recover in the preceding test. In general, the sequence of recovery appeared to be quite independent in each test. If such dynamic variation exists when measured by recovery time, it is not unreasonable to assume that it exists when mortality is the end point observed. Certainly such an assumption can readily explain the redistribution of insects surviving one treatment in their susceptibility to a second treatment.

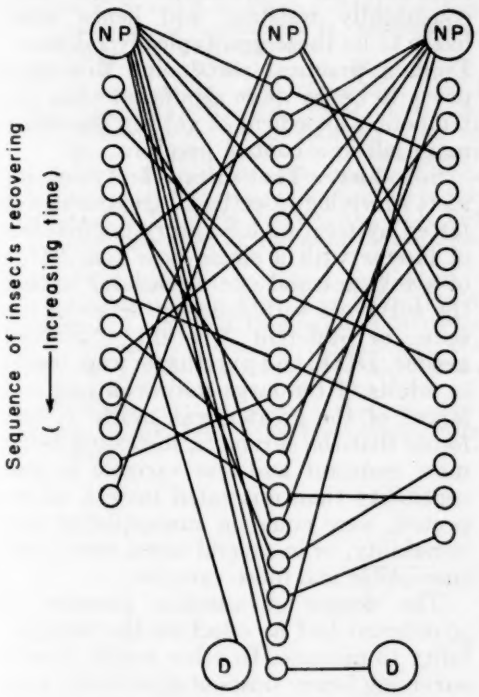

FIG. 1.—Chart showing sequence of individual milkweed bugs recovering from nicotine paralysis in three tests. Each small circle represents an insect, and the lines connect circles representing the same individual in the three tests. Circles marked "N P" include those individuals which were not paralyzed by the dosage administered. "D"=died. If the individual variation was strictly static, all lines would be horizontal and parallel.

DISCUSSION.—In brief reference to the relationship of these results to earlier work, it should be pointed out that the "protective stupefaction" reported by several workers mentioned above is not the same phenomenon as the induction of tolerance which might be encountered with techniques used in the current studies. Stupefaction induced by HCN and knock-down by pyrethrum were "protective" against prompt application of higher doses (or continued administration) of the toxicants, and not when appreciable periods of time intervened between the selecting dose and the final treatment. The absence of mithridation in the silkworm, noted by Campbell (1926), is not denied, but induction of tolerance to arsenic is at least suggested by the above data which indicate that two units of arsenic, applied 4 days apart, killed no more milkweed bugs nor wax moth larvae than a single unit. The observed data showing cumulative effects of DDT are in line with those of Hoffman *et al.* (1951). The data on the response to pyrethrum following nicotine treatment do not confirm Turner's (1951) data, but this may be due to the fact that a greater time interval separated the two treatments. However, Turner's data can be interpreted another way than that the nicotine "conditions" the milkweed bug for a higher mortality from pyrethrum. In his tests the pyrethrum was apparently applied before the full effect of the nicotine was expressed. Thus some bugs might have succumbed from nicotine, but their death was attributed to pyrethrum.

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The contribution of this study to the problem of joint action is largely negative in the sense that it points up problems without clarifying them. It is obvious that it is not easy to differentiate and evaluate the effects of the respective chemicals even when they are administered a week apart. A striking example of what can happen is seen in tests in which nicotine was applied in dosage series to milkweed bugs surviving DDT treatment. At the higher dosages, mortality due to nicotine was evident. At lower dosages many insects showed characteristic symptoms, not of nicotine, but of DDT poisoning. Evidently DDT was retained in the body tissues so that its toxic effect was not expressed until released by the nicotine. This conclusion may not be compatible with the observations of Ferguson & Kearns (1949), but the only other explanation is that the DDT effect was delayed several days beyond the usual time for DDT symptoms to appear, and this seems unlikely. It is becoming increasingly evident that physiologic studies of joint action should be made and that statistics alone should not be relied upon to explain the actions of insecticides when applied in combination. This emphasizes the plea to this effect made by Hewlett & Plackett (1950). In any case the concept of dynamic variation in individuals complicates rather than simplifies interpretations, and, if found to be generally true, renders particularly difficult the application of the hypothesis of Plackett & Hewlett (1948).

The contribution of this study to an understanding of the phenomenon of insect resistance to insecticides has already been communicated (Beard 1952). Briefly, the concept of dynamic variation in individuals throws open to question the technique of selecting individuals for breeding on the basis of the dosage-mortality curve and the belief that individuals surviving chemical treatment are genotypically the most resistant. These studies point to distributions, probably mutually independent, of three variations: (1) variation in response by the individual insect (dynamic variation), (2) variation in response by individuals about the group mean at a particular time (expressed by the slope of the dosage response curve), and (3) variation of the means of test groups (considering the entire population of the species at all times), which is manifested by the different responses found from time to time, from place to place, and under different conditions. Recognition of these three types of variation may clarify situations which now appear in conflict, particularly if the physiologic and ecologic factors contributing to each can be identified.

Although direct application to practical control operations of the principles indicated here is not warranted, the data at least suggest that single large applications of nicotine and arsenic might be more effective than repeated applications involving small dosages. On the other hand, repeated dosages of DDT and pyrethrum might be more effective than a single massive dose because of their "sensitizing" action. This latter condition, however, is one which is most favorable for the development of resistance to insecticides because the survivors would represent the individuals which were consistently resistant and hence most likely to be those genotypically resistant. From a practical standpoint this may prove to be far more significant than the temporary expedient of getting the maximum kill in a control program.

SUMMARY.—The susceptibility of insects surviving insecticidal treatment was tested by treating laboratory populations of insects with a single dose (ca. LD_{50}) of a toxicant and one week later testing the survivors with a dosage series of the same or different toxicant. Nicotine, arsenic, DDT, and pyrethrum were tested in adults of the large milkweed bug and larvae of the greater wax moth. It was found that the survivors, instead of being more resistant and less variable in susceptibility than untreated insects, as expected, were equal in susceptibility and variability, or in several cases, even more susceptible and more variable.

The degree of selective pressure of pyrethrum had no effect on the susceptibility to nicotine. In other words, insects surviving heavy doses of pyrethrum were no more resistent to nicotine, in comparison with untreated controls, than insects surviving light doses of pyrethrum.

As tested by administering two unit doses at different times in comparison with two unit doses administered at the same time, arsenic appeared to be eliminated by both *Oncopeltus* adults and

Galleria larvae; nicotine appeared to be eliminated by *Galleria* larvae; but was additive in *Oncopeltus;* both DDT and pyrethrum showed some sensitizing activity, and in general were more additive.

The pattern of susceptibility of chemically-selected insects being essentially the same as that of unselected insects, even in the absence of additive effects, suggests a dynamic type of variation among individuals.

Dynamic variation was further demonstrated when recovery time was used as the criterion for effectiveness of stupefacients (carbon dioxide, nicotine, cyanide).

Dynamic variation could help explain some conflicting concepts in the problem of development of resistance to insecticides and helps to explain the conditions under which resistance might develop.

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Relation of Absorption and Metabolism of Octamethylpyrophosphoramide by Pea Plants to Available Phosphorus[1,2]

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Development of chemicals possessing systemic insecticidal properties has progressed rapidly since the pioneer work of Schrader (1947) on toxic organo-phosphates. The most widely recognized of these compounds is octamethylpyrophosphoramide. Large scale use of this material for insect control has necessarily been limited due to insufficient knowledge of its mode of toxic action to insects, mammals, and plants.

Adequate reviews are available on the selective toxicity and biological relationships (Martin 1949; Ripper *et al.* 1949, 1951), chemistry (Ripper *et al.* 1950; Hartley & Heath 1951; Hartley *et al.* 1951), and the composition and analysis (Hartley *et al.* 1951; Hall *et al.* 1951; David *et al.* 1951) of octamethylpyrophosphoramide (OMPA). OMPA is fairly stable in neutral or alkaline solutions but is hydrolyzed rapidly in acid to yield orthophosphate and dimethylamine. The insecticidal activity of OMPA is low until metabolic "activation" of the chemical occurs (Metcalf & March 1949; DuBois *et al.* 1950). The ability of plants to activate OMPA has been disputed (Zeid & Cutkomp 1951). More conclusive evidence has been presented on the ability of liver slices to convert OMPA to a more toxic metabolite (DuBois *et al.* 1950; Gardiner & Kilby 1950). Neither the chemical nature nor the origin of this active metabolite, an effective cholinesterase inhibitor, is known.

The investigation reported here concerns the relation of available phosphorus to the absorption and metabolism of octamethylpyrophosphoramide by pea plants. The practical value of OMPA on peas has been clearly demonstrated (Davich & Apple 1951; Bronson & Dudley 1951). The amount of available phosphorus has been considered as a possible factor affecting the absorption or metabolic breakdown of this insecticide by plants inasmuch as orthophosphate is a definitive hydrolytic product of OMPA, and it is also metabolically active in many plant processes.

Assay Methods.—Three assay methods have been used in studying pea plants treated systemically with OMPA: 1) direct chemical determination of unmetabolized OMPA in the plant, 2) evaluation of the activated compound present by the ability to inhibit cholinesterase enzyme, and 3) bioassay of the toxicity of the plants utilizing pea aphids. Treated plants were compared by the three methods to determine the extent to which an experimental variable affected each of these end points.

Chemical Analysis.—Chemical analysis for OMPA present in plants was made by an adaptation of the procedure of Ripper *et al.* (1950). The following procedure proved satisfactory for analyzing samples of one or a few plants for octamethylpyrophosphoramide content.

From 0.4 to 4.0 gm. wet weight of fresh plant tissue were macerated using a Waring blendor or a mortar and pestle with white sand; the resulting brei was then diluted with water and strained. The filtrate was made N/10 in sodium hydroxide, diluted to 20.0 ml. and then maintained at 80° C. for 30 minutes, cooled, strained and extracted with 30.0 ml. chloroform (U.S.P.). The chloroform extract was then clarified by centrifugation and 20.0 ml. of it transferred to a 1 by 8 inch pyrex digestion tube. After adding several glass beads, the chloroform was evaporated to about 2 ml. residue; 2.0 ml. perchloric acid (C.P.—60 per cent) was added, and the tube heated with a microburner until about 0.2 ml. per chloric acid remained. Phosphorus was determined in the form of reduced phosphomolybdate by absorbance at 840 mμ 20 minutes after 10.0 ml. of molybdate solution and 2.0 ml. of amidol reducing agent (Allen 1940) were added to the tube. The phosphorus content multiplied by the factor 7.87 gave the OMPA content

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[2] Presented Dec. 10, 1951 at the national A.A.E.E. meeting in Cincinnati.

of the original plant material. Concentration was expressed as mgm. OMPA per gm. dry weight, the per cent dry weight of the plants having been determined from a comparable sample of plant material.

The method determines those phosphorus compounds that partition into chloroform following aqueous alkaline hydrolysis in N/10 NaOH for 30 minutes at 80° C. No interference from naturally occurring phosphorus compounds was encountered in any of the analyses. The factor 7.87 is based on the partitioning data of Ripper *et al.* (1950) and corrects for aliquot size, partition coefficient and molecular weight difference between OMPA and phosphorus. Of the impurities present in technical grade OMPA, only triphosphoric penta(dimethylamide) is of sufficient alkaline stability to interfere in the above analysis (Hartley *et al.* 1951), and since this chemical possesses systemic insecticidal properties similar to OMPA, a further chemical differentiation was not made. Because of the alkaline instability of OMPA metabolities, this analysis would essentially be a determination of the reservoir insecticide in the plant available for metabolism into a more toxic derivative as discussed later. Analysis was made on fresh plants to avoid danger of insecticide loss on drying, but was expressed on a dry weight basis for greater uniformity. Twenty separate analyses from the same plant homogenate gave a precision for the method of 9.7 parts per thousand. The insecticide used[1] analyzed as 73.2 per cent pure by the described procedure.

Anticholinesterase determination and formation of ChE inhibitor.—Cholinesterase (ChE) activity was measured manometrically according to the method described by DuBois *et al.* (1950) with rat brain homogenates as the enzyme source (25 mgm. wet weight of tissue in 2 ml. total liquid volume per flask). Comparisons were made on the basis of the total activity over a one-hour period, at which time a linear realtionship existed between enzyme concentration and per cent hydrolysis of substrate. To determine the presence of an anticholinesterase agent in peas, the tissue was macerated in Ringer bicarbonate buffer (2.5 gm. wet tissue in 50 ml.) with a cold Waring blendor; the brei was then strained and 1.0 ml. of the filtrate added immediately to the Warburg flasks containing the other components of the ChE system in a liquid volume of 1.0 ml. Control determinations were made with similar homogenates from untreated plants but in no case did these alter the ChE activity significantly. The results of inhibitor studies are reported on a dry weight basis. This enzyme assay method was also found of value in determining the presence of other anticholinesterase compounds in extracts from plant tissue by a procedure similar to that reported by Giang & Hall (1951).

The metabolic "intoxification" of OMPA by plants has been a subject of controversy. DuBois *et al.* (1950) found that 1 per cent homogenates of OMPA-treated lettuce inhibited ChE, and therefore suggested that the plant converted OMPA to an anticholinesterase agent. Hall *et al.* (1951) found that chloroform extractives of treated bean plants showed a 700× enhancement in anticholinesterase

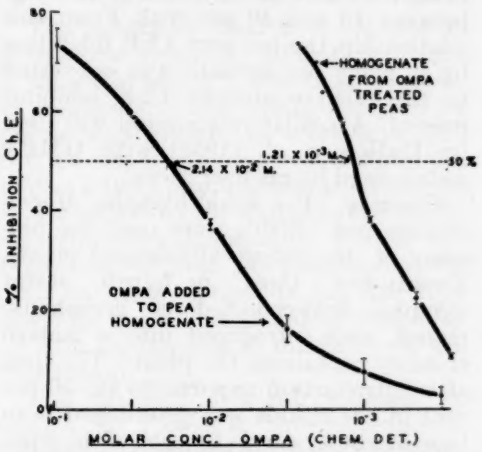

FIG. 1.—Ability of OMPA to inhibit cholinesterase (ChE) before and after metabolism by pea plants. (Individual values of paired determinations indicated by brackets about treatment means.)

effect over the insecticide prior to passage through the growing plant. Zeid & Cutkomp (1951), however, were unable to obtain evidence that the compound was made more toxic within the plant. In order to determine whether the anticholinesterase activity of OMPA was enhanced in pea plants, a comparison was

[1] Monsanto Chemical Company—

octamethylpyrophosphoramide	70%
related organic phosphates	20%
inert ingredients	10%

made between homogenates of OMPA-treated plants and untreated plant homogenates with OMPA added. The amount of plant homogenate added to the assay system was constant throughout and chemical analysis for unmetabolized OMPA was used to determine the concentration of OMPA present in each case. The result (Fig. 1) shows that the amount of "added" OMPA required to inhibit ChE 50 per cent was 18 times as much as was actually present in the sap of treated plants with the same inhibitory action. These results indicate the formation of a ChE inhibitor within pea plants more effective than OMPA *per se*. Further studies showed 18× as a near minimum figure for this discrepancy; much greater differences were obtained where the plants were in a more rapid state of growth. The curve on the right in figure 1 may be considered as essentially due to the formed inhibitor, and the logarithm of the inhibitor concentration bears a linear relation to the per cent ChE inhibition in the range between 10 and 40 per cent. From this relationship the per cent ChE inhibition by a plant homogenate was converted to the relative amount ChE inhibitor present. A similar relationship was used by DuBois *et al.* (1950) with OMPA metabolized by rat liver slices.

Bioassay.—Pea aphid nymphs, *Macrosiphum pisi* (Kltb), were used for bioassay of the systemically-treated plants. Twenty-five third or fourth instar nymphs, field-collected or greenhouse reared, were introduced into a lantern chimney containing the plants. The time after introduction required to kill 50 per cent of the aphids was determined from time-mortality curves for each of the replicates. Although more sensitive than the other methods, the bioassay was also more variable.

GENERAL EXPERIMENTAL PROCEDURE.—Octamethylpyrophosphoramide is the first phosphate insecticide available in large quantities that is both completely soluble and sufficiently stable in water for nutrient solution investigations. Studies reported here with OMPA were made in soil, sand, and nutrient solution cultures. Nutrient solutions contained the following elements, concentrations being expressed as parts per million: P-165, K-208, N-134, Ca-163, Mg-49, S-65, Fe-15, Mn-0.5, B-0.5, Zn-0.4, Cu-0.1, and Mo-0.1. The aerated solution cultures were maintained in 3-liter battery jars while the silica sand cultures were in pint cans. All solutions were adjusted initially to pH 6.5 and readjusted as necessary to maintain the solutions at pH 6.3–6.7. A standard stock of Perfection variety peas was used. The young plants were transplanted into the nutrients when about 8 cm. tall after the cotyledons had been removed from the plants so that elemental deficiencies would appear more rapidly; similar results were obtained, however, when the cotyledons were present. The insecticide was applied 7 days prior to analysis to allow time for absorption and metabolism of the OMPA. Five or six replicates were used per treatment.

This general experimental procedure was modified for some of the studies. No added nutrients and no pH control were utilized in determining OMPA absorption from various soil types. Three-liter nutrient solution cultures, both complete and phosphorus-deficient, were used in studying the phytotoxicity of OMPA and the absorption of OMPA from solution as a function of time and OMPA concentration. Phosphorus-level studies were made in silica sand cultures and a seven-day period for the plants to build up their phosphorus supply was allowed prior to introducing the insecticide. Silica sand cultures were also used for a study on the effect of varying insecticide concentration on the toxicity of treated plants. The peas were systemically-treated by introducing the OMPA into the nutrient solution. With sand cultures 25 ml. of an aqueous solution of OMPA was poured onto the surface of the sand while with the solution cultures the nutrient was prepared with a known concentration of OMPA present. Modifications of this general plan peculiar to the particular experiment are indicated with the experimental results.

EXPERIMENTAL RESULTS.—*Solution Concentration of OMPA.*—As the nutrient solution concentration of OMPA is increased, the insecticide uptake, units ChE inhibitor formed, aphid kill and per cent dry weight of the plants vary as shown in figure 2. The most striking relation shown in the graph is the parallelism between the amount of insecticide present in the plant, the relative units of ChE inhibitor

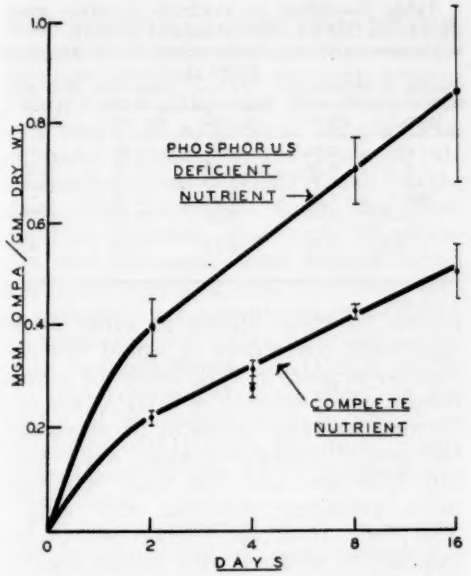

FIG. 2.—Effect of concentration on absorption of OMPA by the roots and subsequent toxicity of OMPA-treated pea plants.

present, and the per cent dry matter of the plants. This indicates that under these conditions the amount of OMPA absorbed determines the amount of ChE inhibitor present. The rate of aphid kill increased with OMPA concentration to the point at which the per cent dry matter of the plants showed a marked rise. The aphids would not feed as readily on the stunted plants (with higher per cent dry matter). The bioassay method was most sensitive at the low insecticide concentrations while the precision of the chemical determination was greatest at intermediate, and of the anticholinesterase measurements at highest insecticide concentration. Each assay method probably measures a different effect. Further studies utilized a 1 to 250 dilution as it allowed comparison of all three factors.

Absorption and Metabolism.—The ease of absorption of OMPA by the plant roots may vary with soil type. The toxicity of systemically-treated plants on seven different soil types was tested using aphid kill for comparisons. Each soil was nearly saturated with water and identical amounts of OMPA added to the soil solution phase. The results (Table 1) show that those plants in silica sand were the the most toxic, but the other sands did not differ significantly from the silica sand. On the other hand the plants on soils other than sand (with smaller particle size and higher content of organic matter) required a significantly longer time than those on sand for aphid kill. A tendency was also noted among the sandy soils for the sands of higher phosphorus content to require a longer time for aphid kill.

Table 1.—Effect of soil type on aphid kill following soil application of OMPA.

SOIL	AVAILABLE P (lbs./A.)	HRS. 50% APHID KILL
Silica sand (control)	trace	4.43
Plainfield sand	60	5.25
Greenhouse sand	90	5.40
Miami silt loam	200	7.18
Peat	180	8.12
Parr silt loam	30	8.23
Superior clay	80	8.27
		L.S.D. = 1.64 0.05
		L.S.D. = 2.21 0.01

The uptake of OMPA in relation to phosphorus supply as a function of time is shown in figure 3. Plants were grown in solution cultures, either complete or phosphorus-deficient, for seven days, then OMPA was introduced into the solution to give a 100 p.p.m. concentration and the rate of uptake by the plant was chemically determined. A significantly greater uptake occurred from the phosphorus-deficient nutrients in three of the four time intervals (a possible sampling error may account for the lack of difference on the fourth day).

The toxicity of plants exposed to OMPA for 7 days in both phosphorus-deficient or complete nutrients was determined by bioassay. The data are not included here, but with the three insecticide concentrations utilized the phosphorus-deficient plants were more toxic to aphids than those grown on complete nutrients, the greater difference occurring with the lower concentrations of OMPA. With one of these concentrations, seven other trials of complete versus phosphorus-deficient nutrients were made in the greenhouse over a 6-month period. In all cases plants in a minus phosphorus nutrient were significantly more toxic than those in a complete nutrient.

The most complete experiment on phos-

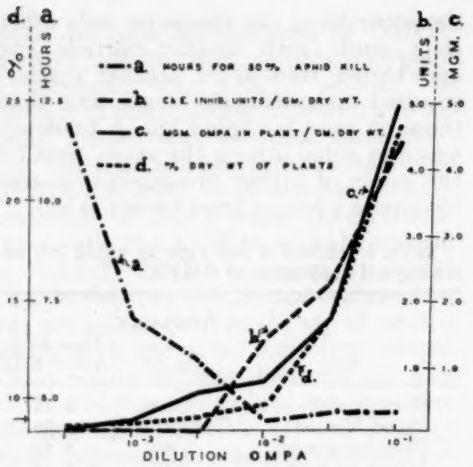

FIG. 3.—Relative uptake of OMPA by pea plants from two types of nutrient solutions. (Brackets about treatment means indicate standard deviation of the treatment.)

phorus level in relation to OMPA uptake is shown in table 2. As the phosphorus in the nutrient solution increased, the phosphorus in the plant increased but the amount of absorbed OMPA decreased, as did the units of ChE inhibitor present. A corresponding increase in the time required for 50 per cent aphid kill was observed. That is, as the available phosphorus in the solution increased, the systemic toxicity decreased as measured by all three assay methods. This inhibition of the toxicity of OMPA by solution phosphorus might be caused by any or all of three general mechanisms: 1) decreasing the ability of the plant to absorb OMPA through the roots, 2) decreasing the rate of formation of the active metabolite from the OMPA "stockpile" within the plant, or 3) increasing the rate of the subsequent degradation of the active material.

The first of these suggested mechanisms could be eliminated if the OMPA-phosphorus interaction occurred with foliage application since no absorption through the roots would be involved. The nature or presence of an OMPA-phosphorus interaction with foliage application was determined by an experiment identical in design to that discussed above. A standard amount of OMPA was applied to the foliage by a settling mist procedure (Allen *et al.* 1943), the soil being covered with waxed paper. The plants gave essentially the same analyses for total phosphorus as those shown in table 2. No significant differences in aphid kill and number of units of ChE inhibitor formed from a given amount of OMPA occurred between the four levels of phosphorus—the time of 50 per cent aphid kill averaging 6.74 hrs. and the ChE inhibition units averaging 0.63/gm. dry weight. The fact that no OMPA-phosphorus interaction occurred with foliage application fails to indicate that the rate of metabolism of OMPA in the leaves is the explanation of this interaction.

Table 2.—Effect of available solution phosphorus on OMPA absorption and toxicity.

PHOSPH. IN NUT. SOL. (ppm.)	PHOSPH. IN PLANT (% dry wt.)	OMPA IN PLANT (mgm./gm. dry wt.)	UNITS ChE (inhib./gm. dry wt.)	HRS. 50% APHID KILL
0	0.78	4.14	4.20	4.82
5	0.88	3.74	3.95	5.03
40	1.17	3.43	3.81	5.35
320	1.83	1.90	3.18	6.78
L.S.D. .05	0.15	0.54	0.46	0.73
L.S.D. .01	0.21	0.75	0.66	1.02

The development of insecticidal activity from OMPA applied directly to the seeds requires both translocation and metabolic activation. If phosphorus inhibition is effected through either of these processes, then seeds treated with the same amount of OMPA should utilize this given amount at different rates when grown on complete and on phosphorus-deficient nutrients. To test this hypothesis, seeds were soaked in OMPA solution, surface washed and introduced into complete or phosphorus-deficient nutrients in sand culture. Chemical analysis of seeds showed an initial average OMPA content of 2.64 mgm. per seed. After two and one-half and four weeks no difference in aphid kill occurred between the two treatments—an over-all mean of 5.4 hours being required for 50 per cent kill at 2.5 weeks and 14.5 hours after 4 weeks. Analysis of the plants at the end of four weeks showed 0.015 mgm. OMPA residue in the cotyledons, and 0.093 mgm. in the rest of the plant. No significant differences were found in the non-translocated OMPA in the cotyledons, the residual in the rest of the plant, or in the total amount present per plant between the complete and phosphorus-deficient nutrients. The total phosphorus content of the plants as per cent dry weight at the end of the fourth week was: phosphorus

deficient nutrient—controls 0.48 per cent, treated 0.59 per cent; and complete nutrient—controls 1.14 per cent, treated 1.25 per cent. Although the phosphorus level was twice as great in the plants on complete nutrient, no difference in rate of disappearance of OMPA and of the insecticidal properties from the plant could be detected. Since only translocation and metabolic rates were involved and not absorption, this experiment fails to indicate that the phosphorus-OMPA interaction is due either to translocation or to metabolism rate for OMPA within the plant. This leaves an effect on the ability of the active root to absorb or metabolize OMPA as the most likely explanation of the OMPA-phosphorus interaction.

The factors responsible for the interaction between OMPA and phosphorus appear to be centered in the roots. The greater uptake of OMPA by plants on phosphorus-deficient nutrient than those on complete nutrient was also detected by determining residual OMPA in the nutrient solution. Analysis of the solutions used in the experiment summarized in table 3 showed that a significantly greater amount of OMPA remained in the complete than in the phosphorus-deficient nutrients at 40 p.p.m. original OMPA after seven days of plant growth. Experiments were made to investigate whether the rate of uptake by the plant or the rate of breakdown outside the plant roots was the cause of this difference. Excised roots were incubated in the presence or absence of orthophosphate with 1×10^{-4} M. OMPA (2.00 gm. fresh roots per 50 ml. solution) in unbuffered solutions and in solutions buffered at pH 5.0 and 7.0. Despite the relatively large amount of root tissue exposed and the small amount of OMPA present, the OMPA could be recovered almost completely in unchanged form (98 to 102 per cent) from the various treatments at the end of a 16-hour incubation period at 37° C. These experiments failed to indicate that extracellular root metabolism is the cause of the interaction. Determination of the relative growth rates of roots on intact plants showed that those in in phosphorus-deficient nutrients grew less rapidly (dry wt. basis) than those in complete nutrients; this indicated a smaller total root surface available for absorption with plants on phosphorus-deficient nutrients. Yet a greater OMPA-uptake occurred in the absence of phosphorus. These investigations failed to show the metabolism of OMPA extracellular to the roots or the relative root surface available for absorption as the cause of the interaction. It is therefore proposed that the ability of phosphorus to inhibit the formation of toxicity in OMPA-treated peas is through an effect on active absorption or the actual process involved in penetration of OMPA into the roots.

Phytotoxicity.—OMPA is capable of either inhibiting or accelerating the rate of plant growth. When applied to peas at high concentration it causes an initial decrease in growth rate followed by the appearance of chlorotic spots and a marginal leaf chlorosis leading finally to necrosis. With soil application to peas the injury first appears on the lower leaves and only in extreme cases will it produce visible injury in the terminal bud region. Phytotoxicity experiments were made with pea plants and various combinations of nitrogen and phosphorus deficiencies in 3-liter nutrients. No significant interactions were found between OMPA and the deficiencies. When used at 1000 p.p.m. of actual OMPA, the technical grade material (42 per cent OMPA) was significantly more phytotoxic (based on dry weight gain during growth) than a purified sample (70 per cent OMPA) when analyzed over all the deficiency treatments; in a similar experiment with 200 p.p.m. of purified OMPA a significant inhibition of plant growth did not occur over the nutrient deficiencies tested. As shown in figure 1, the per cent dry matter of OMPA-treated peas closely parallels the amount of unmetabolized OMPA present and the relative amount of anticholinesterase substances present. With these plants the total weight gain during growth decreased directly as the per cent dry matter increased. In several experiments it was noted that low concentrations of OMPA accelerated the growth (gain in total dry weight) of the plant and caused an increase in the moisture content over untreated plants. These general observations on the phytotoxicity of OMPA indicate that the growth rate of the plant is determined by the amount of OMPA absorbed or by the

Table 3.—Effect of phosphorus on the phytotoxicity of OMPA to pea plants.

NUTRIENT SOLUTION	CONC. OMPA IN NUTRIENT	AVE. DRY WEIGHT PLANTS (GMS.)	TOTAL *P* AS PER CENT DRY WT.	Q_{O_2} STIPULES AT BASE OF TERMINAL BUD	RELATIVE PHOSPHATASE ACTIVITY OF TOPS
Complete (165 ppm. *P*)	0 ppm.	0.173	0.66	9.37	0.794
	40 ppm.	0.143	0.68	8.75	0.781
	200 ppm.	0.136	0.71	8.62	0.727
	1000 ppm.	0.092	0.81	9.02	0.595
Phosphorus deficient (0 ppm. *P*)	0 ppm.	0.153	0.26	9.28	1.000
	40 ppm.	0.142	0.30	8.03	0.902
	200 ppm.	0.107	0.33	8.44	0.788
	1000 ppm.	0.086	0.72	8.87	0.639
L.S.D. .05		0.023	0.15	0.42	0.066
L.S.D. .01		0.032	0.21	0.56	0.091

amount of "activated" material formed.

The relation of phosphorus and OMPA to several aspects of the metabolism of pea plants was investigated. Data from one of these experiments appears in table 3. The peas were grown 14 days in the appropriate solution and then the dry weights, total phosphorus (Allen 1940), Q_{O_2}, and relative leaf phosphatase activity were determined. The Q_{O_2} (μl O_2 uptake /mgm. dr wgt./hr.) was determined on the eighth day with the stipules at the base of the terminal bud, none of this tissue showing visible signs of insecticide damage. Q_{O_2} determinations were made in a Warburg respirometer at 25° C. with six replicates per treatment. The oxygen consumption was less for phosphorus-deficient plants than for those on a complete nutrient. Further, the oxygen uptake was lowered in the OMPA-treated plants, with the lower concentrations causing the greater deviation from the untreated. Yet OMPA as high as M/10 failed to alter the Q_{O_2} of pea stem sections suspended in 0.02 M. glucose. The phosphorus-deficient plants had a lower moisture content and less rapid foliage and root growth than those on complete nutrient. The physiological effects of OMPA on pea plants cannot be adequately explained on the basis of the inorganic phosphorus available to the plant from the breakdown of this organic pyrophosphate.

Phosphatase enzyme activity.—Since the activity of phosphatase enzymes is affected by certain phosphorus compounds, the relation of OMPA to this enzyme system was investigated. In preliminary studies with barley malt acid phosphatase it was found that tetraethyl pyrophosphate was an effective inhibitor, but that its activity was lost on acid or alkaline hydrolysis. On the other hand OMPA was an ineffective inhibitor but after hydrolysis in acid a high degree of inhibition occurred due to the liberation of orthophosphate which competitively inhibits many phosphatases. The conditions for pea phosphatase activity were found to be optimal at pH 5.7 when tested with a p-nitrophenyl phosphate substrate in a M/40 ethylene diamine-citrate buffer. The p-nitrophenol liberated by the enzyme was determined colorimetrically as the sodium salt at 400 mμ. Interfering plant pigments were removed prior to analysis for phenol ions by an ether extraction from acidified solution, followed by an alkaline extraction of the ether to remove the p-nitrophenol, leaving the plant pigments in the ether fraction. The relative phosphatase activity shown in table 3 was determined from samples of the foliage which had been air-dried and finely ground, a treatment which may have destroyed the active OMPA metabolites. A higher phosphatase activity of plants grown in a phosphorus-deficient nutrient is evident. The decline in activity with increasing OMPA in the nutrient closely parallels the total phosphorus content of the plants and thus might be due to OMPA, orthophosphate or other metabolites formed.

Extracellular root phosphatase enzymes were also investigated in relation to

OMPA and phosphorus. The pH optimum of these enzymes for peas with M/100 acetate buffer on p-nitrophenyl phosphate substrate was found to be in the range of pH 3 to 5 with no sharp optimum, but with a rapid decline in activity in more alkaline solutions. Preliminary experiments showed that the decreasing ability of plants to absorb OMPA from solution as the phosphorus level increased was paralleled by a decrease in extracellular root phosphatase activity. A positive correlation between extracellular root phosphatase activity and OMPA breakdown in solutions exposed to excised roots could not be demonstrated. When 2.00 gm. samples of roots with high phosphatase activity were incubated 16 hours at 37° C. with 1×10^{-4} M. OMPA, the OMPA could be almost entirely recovered in unchanged form (98 to 102 per cent) at the end of this incubation period. Similarly no metabolism of OMPA occurred with roots in which the presence of fluoride or orthophosphate had almost completely inhibited these enzymes. It was found, however, that the extracellular root phosphatases were inhibited by 1×10^{-4} M. OMPA on prolonged incubation (6 per cent in 30 minutes, 37 per cent after 16 hours), and that this inhibition was reversible by washing the roots in distilled water. This inhibition could not be explained by the effect of OMPA *per se* or the amount of free orthophosphate present. The reversal of the inhibition may be due to removing a competitive inhibitor or washing away the inhibited secreted enzyme. Even though no chemical evidence was obtained for breakdown of OMPA by excised roots, it was found that extracellular root phosphatases are inhibited on prolonged incubation in the presence of OMPA.

DISCUSSION.—Octamethylpyrophosphoramide is metabolized by plants, forming an active cholinesterase inhibitor before final breakdown to orthophosphate, dimethyl amine and other degradation products. Three factors may alter the toxicity of systemically-treated plants: 1) The ability of plant tissue to absorb and translocate the OMPA, 2) the rate of metabolic intoxification of the insecticide, and 3) the stability of the active metabolite within the plant.

Absorption of OMPA from soil or solution is altered by available orthophosphate, the systemic toxicity decreasing as the solution phosphorus is increased. With foliage or seed application this OMPA-phosphorus interaction does not occur with peas, indicating an effect on absorption by the roots. Experiments with isolated roots failed to show that extracellular OMPA metabolism could explain this interaction. Despite their lower growth rates and smaller total root surface, plants in low or phosphorus-deficient nutrients take up OMPA from solution at a greater rate than plants in high phosphorus nutrients. Only five parts per million of phosphorus in the nutrient is sufficient to reduce the OMPA taken up from solution. The primary effect of phosphorus would therefore seem to be on active absorption of OMPA by the roots rather than on translocation or metabolism of this compound or on the growth rate or relative root surface of the plants. A previous report of an essential element affecting absorption of a systemic insecticide was made by Hurd-Karrer (1937) with the effect of sulfur on selenium absorption.

The metabolism of OMPA may also be altered by phosphorus. The rate of disappearance of OMPA from peas following seed application was not affected by phosphorus supply. The amount of active inhibitor formed from OMPA following foliage application was also unaffected by phosphorus level in the plant. With plants of similar phosphorus content exposed to varying solution concentrations of insecticide (Fig. 1), a close parallel appeared between relative amount of cholinesterase (ChE) inhibitor and amount of insecticide present. On the other hand, the active ChE inhibitor present from a given amount of insecticide absorbed by the roots appears to be altered by phosphorus level (Table 2), a greater proportionate amount of inhibitor occurring in high phosphorus plants. Using the general experimental method of Gardiner & Kilby (1950) the effect of phosphorus on the ability of rat liver slices to form an active ChE inhibitor from OMPA was investigated. It was found that as the phosphorus concentration of the buffer was increased, the amount of active inhibitor present after incubation with the slices decreased. Phosphorus also inhibits the metabolism of the insecticide nicotine by liver slices (Werle &

Uschold, 1948). Knowledge of the mode of action of phosphorus in the metabolic intoxification of OMPA and in the subsequent detoxification of the active metabolite awaits further investigation on the chemical nature of this process. The above discussion indicates that the OMPA which occurs in the plant following absorption is present in sufficient amounts to serve as a reservoir from which the active metabolite is formed and broken down at a rate governed by factors affecting the limiting reaction in the process.

Phosphatase enzymes are inhibited not only by orthophosphate, but also by certain organic phosphates. The nature of leaf phosphatases has been previously investigated by Ignatieff & Wasteneys (1936) and Yin (1945), while that of the extracellular root phosphatases has been reported by Rogers *et al.* (1942). For the leaf phosphatase determinations, the *in vivo* inhibition might be due to OMPA, free orthophosphate or other metabolites of OMPA. Inhibition of the root phosphatases could not be explained on the basis of the original insecticide or the orthophosphate formed during the incubation period. There is evidence for the theory that inhibitors of hydrolytic enzymes transfer a group of the inhibitor to the active enzyme center at the time of inhibition (Whittaker 1951, Jansen *et al.* 1951). The inhibition of root phosphatase after a period of incubation could then be due to the combination of the phosphatase with an OMPA metabolite formed by this enzyme, the metabolite being formed in such low concentrations that no resulting decrease in amount of OMPA could be detected. It is of interest to note that the regions of the plant highest in phosphatase activity (Ignatieff and Wasteneys 1936; Yin 1945) are also those regions of OMPA-treated plants which are most toxic to plant feeding insects.

The phytotoxicity of OMPA to pea plants also appears to be related to available phosphorus. Although *in vitro* experiments showed no reduction in Q_{O_2} of plant tissue suspended in M/10 OMPA, very small amounts *in vivo* caused a marked Q_{O_2} reduction. This reduction in respiration rate is opposite to the stimulation occurring with increased phosphorus. The effect of OMPA on the leaf phosphatase activity reported here and on the carbohydrate content reported by Zeid & Cutkomp (1951) can be partially explained on the basis of the phosphorus contributed by the insecticide. Plant stimulation by the phosphate insecticides (Wolfenbarger 1948; Tsi 1950, and others) has been considered to result from available nutritional phosphorus derived from the insecticide. The degree of stimulation that occurs cannot be accounted for on the basis of the small additional amount of phosphorus supplied by the insecticide. Further, the ease of degradation of many of these compounds to available phosphorus is not great. Even if such a degradation did occur the level of insecticide needed for stimulation on the basis of phosphorus supplied would be so large as to stunt or even kill the plant, nullifying any accompanying beneficial action. The pronounced physiological effects of the phosphate insecticides on plants is more likely due to affecting some enzyme such as phosphatase or acetyl esterase (Jansen *et al.* 1948) or to an effect due to the bond energy of the phosphate linkage (Oesper 1950) as suggested for TEPP by Hall (1951).

Binding of soil insecticides on the surface of soil particles will reduce their effective concentration. Wallace (1951) reported no difference in toxicity of OMPA-treated plants between sand and another soil type while David (1951) found a greater uptake of radioactive OMPA from sand. The study reported here also indicates systemic toxicity differences in plants on sand and those on other soil classes. In field usage, the varying effectiveness of OMPA when applied to the soil depends on a large number of factors. Controlled greenhouse studies have shown that soil type and the amount of available soil phosphorus are two of these factors.

An investigation of the chemical nature of the active metabolite of OMPA as well as well as factors affecting its formation and stability, is now in progress.

SUMMARY.—1. Quantitative methods are described for determining the octamethylpyrophosphoramide present in treated plants, the amount of cholinesterase (ChE) inhibitor present, the toxicity of the plants to aphids and the relative activity of leaf and extracellular root phosphatase enzymes. Possible interaction of OMPA and phosphorus was studied in pea plants with each of the above criteria for comparison.

2. The formation of an effective ChE inhibitor from OMPA was demonstrated with systemically-treated pea plants.

3. Phosphorus appears to decrease the insecticidal effectiveness of pea plants grown in OMPA-treated soil or nutrient solutions. This was experimentally demonstrated by varying the available inorganic phosphorus concentration, the insecticide concentration, and the time of exposure to the insecticide. As the solution phosphorus increases, less insecticide is absorbed, less active cholinesterase inhibitor is present, and the insecticidal toxicity of the plants decreases.

4. The interaction of phosphorus and OMPA appears to be due to an effect on active absorption by the roots. This interaction occurred in all cases with soil application where the OMPA must be absorbed by the roots, translocated and then metabolically activated. No interaction occurred with seed application where only translocation and metabolism are involved. Similarly, no interaction could be detected with foliage application in which the penetration of OMPA into the leaf and subsequent metabolism are involved. Attempts to correlate this interaction with growth rate of the roots or of the plant, or with the breakdown of OMPA extracellular to the roots were unsuccessful. It was observed that phosphorus affects the rate of OMPA metabolism, but the mechanism of this action has not been elucidated.

5. OMPA and phosphorus also interact in certain effects on the plant metabolism. The liberation of free inorganic phosphate from the insecticide within the plant may explain the increase in the carbohydrate content and inhibition of leaf phosphatase enzyme activity of treated plants, but is inadequate to explain the inhibition of extracellular root phosphatases, the *in vivo* reduction in respiration rate, or the growth stimulation by OMPA.

6. Soil type, and available soil phosphorus, may alter the effectiveness of OMPA.

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Control of Citrus Thrips with Dieldrin[1]

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Citrus thrips, *Scirtothrips citri* (Moult.), has been a major pest of citrus in California and Arizona for more than 40 years (Jones & Horton, 1911). It is of economic importance in the San Joaquin and Sacramento Valleys in central and northern California, respectively, and in the foothill regions and desert and interior valleys of southern California. It is not an important pest in the coastal regions of California.

Life history studies of this species by Horton (1918) indicate that from six to eight generations occur per year under conditions in the San Joaquin Valley; McGregor 1944) states that probably 10 to 12 generations occur per year in the warmest localities. Overwintering eggs, which are inserted by the female thrips into tender leaves and twigs during late summer and fall, begin to hatch in late February or early March. The larvae of this first generation feed on new vegatative growth but seldom cause enough damage to warrant control measures; pupation normally occurs in debris under the trees. The second generation, which reaches its population peak about the time of petal fall with varieties of citrus that set one crop of fruit per year, such as oranges, grapefruit, and tangerines, is of great economic importance since it is responsible for the characteristic "ring" scarring of fruit. The time of petal fall for these varieties is normally in late March or early April under the desert conditions in the Coachella and Imperial Valleys, and approximately one month later in the other citrus-producing areas in California. Succeeding generations are of economic importance on "one crop" varieties of citrus mainly because of damage to vegetative growth as the fruit is seldom scarred later than mid-June. However, during certain years fruit damage has occurred to some extent in

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July. In areas where lemons blossom and set fruit over a relatively long period of time both fruit scarring and damage to new growth occur throughout the summer and fall.

The severity of damage caused by citrus thrips varies greatly from year to year. Factors responsible for this variation are not clearly understood, but observations by Jones (1918), Woglum (1928), and Lewis (1935) indicate that certain climatic conditions are important. Badly scarred fruit results in a loss to the grower because of a reduction in grade in fresh fruit markets. It has been estimated by McGregor (1944) that during an average year citrus thrips would damage the equivalent of 1.25 million packed boxes of fruit in Tulare County alone if protective measures were not taken. In addition, new vegetative growth may be damaged to such an extent that over a period of years trees fail to grow normally.

Several insecticide treatments have been used to control citrus thrips, with lime-sulfur sprays (Horton 1915, Woglum 1924, Lewis 1946) and sulfur dusts (McGregor 1928, 1933, 1934, 1944) being the most important until the late 1930's. In 1939 tartar emetic-sugar sprays (Boyce & Persing 1939, Persing *et al.* 1940, Persing & Boyce 1941a) which could be rapidly and economically applied with the spray-duster (Lewis 1940, Persing & Boyce 1941, Boyce 1948, Lewis & Landon 1949, Ebeling 1950, Metcalf & Flint 1951), a machine especially designed for the purpose, began to replace the less effective and more expensive treatments then in use. However, within a few years tartar emetic-sugar sprays were no longer effective in certain groves (Boyce *et al.* 1942. Persing *et al.* 1942, Woglum 1942, Persing & Brown 1944) which was demonstrated to be the result of citrus thrips becoming resistant to tartar emetic. At the present time resistance to this treatment has developed in most areas where extensive applications have been made. Nicotine-sugar sprays (Boyce *et al.* 1942) have been used in groves where thrips have become resistant to tartar emetic but are not reliable under conditions of heavy thrips populations. Since 1946, DDT sprays and DDT-sulfur dusts (Persing 1946, Boyce & Ewart 1946, Ewart 1946, 1946a, 1948) have been used in many groves to control citrus thrips. However, this insecticide has not been favorably received in all areas because of the detrimental effect on beneficial insects, particularly vedalia, *Rodolia cardinalis* (Muls.), the ladybird predator of cottony-cushion scale, *Icerya purchasi* Mask. (Woglum 1946, Ewart & DeBach 1947, 1948, DeBach & Bartlett 1951). Furthermore, since 1949 citrus thrips have not been satisfactorily controlled with DDT in certain groves in the San Joaquin Valley (see Table 4, Groves 2, 3 & 5) which indicates that this species has become resistant to DDT in groves where repeated treatments of this insecticide have been applied over a period of 4 or 5 years.

There is, therefore, a recognized need for a more satisfactory treatment to control citrus thrips than is now available. During recent years several new compounds have been studied for thripsicidal properties by members of the Division of Entomology, University of California Citrus Experiment Station at Riverside, and among those which have shown promise dieldrin has proved to be outstanding for the control of citrus thrips under field conditions. Other investigators (Mayeux & Wene 1950, Sloan & Rawlins 1951) have reported that this insecticide is also promising for the control of onion thrips, *Thrips tabaci* Lind., on onions.

It is the purpose of this report to summarize results obtained with experimemtal treatments of dieldrin for the control of citrus thrips under field conditions in California during the period from 1949 go 1951, inclusive.

APPLICATION AND PLOT EVALUATION METHODS.—All experiments were conducted in commercial orange, lemon, or grapefruit groves in central and southern California. The sprays used in these studies contained 20 or 25 per cent dieldrin wettable powder suspended in water, or emulsifiable concentrate containing one or two pounds of dieldrin per gallon emulsified in water.

In experiments designed for thrips control all treatments were applied with a spray-duster at the rate of 100 gallons per acre per application to plots one or two acres in size with 90 to 120 trees per acre. For the prevention of fruit scarring on oranges and grapefruit a single treatment was applied at time of petal fall when the fruit were about pea-size; for the protection of new growth on lemon

trees two applications were normally made, the first at the time the thrips population reached an average of 0.5 thrips per terminal,[1] usually in May or June, followed by the second treatment in late July or early August. In some lemon groves where the thrips populations remained low throughout the summer only one treatment was applied.

In most experiments the effectiveness of dieldrin was compared with one or more standard treatments, such as nicotine-sugar, sabadilla-sugar, DDT, or tartar emetic-sugar sprays; only in a few experiments was it possible to compare dieldrin-treated plots with untreated plots because of the undesirability of leaving untreated trees in commercial groves.

The amount of fruit scarring was determined by examining all peripheral fruit in a band three to six feet from the ground on each of 16 trees in each plot just prior to time of harvest. With this method, 500 to 2000 fruits per plot, depending on the number of fruits on the trees, were examined for scars and the results expressed as "per cent fruit scarred." A treatment was considered commercially effective if less than 5 per cent scarring occurred.

In plots sprayed to protect new growth the treatments were evaluated by estimating the size of the thrips populations at various intervals after the applications. This was done with the aid of an especially constructed thrips collecting device (Ebeling 1950) which is a modification of the so-called "thripsometer" designed by McGregor (1941). Fifty new growth terminals from each plot were rapped sharply against the screen cover of the device which dislodged any thrips present. These fell through the screen and were entrapped on a removable metal plate covered with a sticky material.[2] The metal plate with the entrapped thrips was then removed and stored in an especially constructed case; the thrips were subsequently counted in the laboratory with the aid of a binocular microscope and the results expressed as "average number of thrips per terminal." A treatment was considered commerically effective so long as the population remained below an average of 0.50 thrips per terminal. The experiments on lemons in southern California were discontinued for the season when the regular petroleum oil sprays were applied for the control of California red scale, *Aonidiella aurantii* (Mask.), usually in September or October.

Two types of residue studies, namely harvest and ABC[3] types, were made. For harvest residues fruit were collected from the experimental plots which had been treated with dieldrin sprays for the control of citrus thrips in a manner simulating commercial applications. In ABC studies, which were designed to develop information on the penetration and persistence of dieldrin residues in lemon peel, fruits were collected from plots especially treated for the purpose. Plots of eight trees each were sprayed over ripe fruit in a thorough-coverage manner at the rate of 25 gallons per tree with a dosage of dieldrin considerably in excess of the minimum amount (on an acre basis) required for citrus thrips control.

For residue analyses quadruplicate samples of 28 fruits (four from each quadrant of seven trees) per plot were collected, care being taken not to touch the fruits with the hands as they were clipped into paper bags. Until the time that the fruits could be processed (24 to 48 hours) they were stored as 10° C. For harvest residue studies the fruits were collected at the normal picking time and the apparent dieldrin determined separately in the peel and in the pulp. The pulp is that part of the fruit, incliding juice, remaining after the peel is removed. In studies to determine the penetration and persistance of dieldrin residues in lemon peel, fruit samples were collected immediately following the applications when the spray deposits were dry, and at various intervals thereafter. The same seven trees were sampled each time.

ANALYTICAL METHOD.—In the absence of specific analytical methods for quantitatively determining microgram-amounts of dieldrin residues, the present residue studies were accomplished with the aid of an improved total organic chlorine method of high precision and sensitivity. The nucleus of the method consists of a quartz tube combustion

[1] A "terminal" refers to the new vegetative growth, approximately a foot in length, at the tip of a branch.
[2] "Deadline."
[3] A—residue adhering to wax layer; B—residue within wax layer; C—residue penetrated below wax layer. This ABC technique was discussed by G. E. Carman and F. A. Gunther in a paper entitled "Factors related to the differentiation of extra-surface and subsurface residues" at the 35th Annual Meeting of the Pacific Branch, American Association of Economic Entomologists, Seattle, Washington, 1951. This technique, which is being adapted to a variety of pesticides, demonstrates in the present studies the penetration of the apparent dieldrin from the surface (A) to the inner portion (C) of citrus peel.

technique (Agazzi *et al.* 1952), which was adapted to the problem of estimating dieldrin residues in citrus fruit.

Heretofore, the usual chlorine methods for studies of pesticide residues have frequently been considered unreliable because of the grossly variable amounts of fatty acids liberated by the rigorous saponification step necessary to liberate organically bound chlorine in the plant extractive mixtures containing the pesticide residues. Although most of these fatty acids could subsequently be removed from the final essentially aqueous reaction mixtures as insoluble barium salts, the barium salts of proprionic, butyric, and some of the pentanoic acids are appreciably water soluble. Therefore, these acids subsequently precipitated along with chlorine as insoluble silver salts in the ultimate titration. Oily and waxy fruit, such as citrus and avocado, are particularly troublesome in this regard. In the combustion technique, the final processed residue is quantitatively burned to CO_2 H_2O, HCl, and oxides of nitrogen and sulfur.

Secondary objections to chlorine methods have devolved from the facts that they do not distinguish between inorganic and organic chlorides and that they are non-specific for the parent chlorinated pesticide. Inorganic chlorides usually can be adequately removed by washing the organic solutions of extractives. In the absence of other halogen-containing organic substances, a non-specific total chlorine combustion method is adequate for the present purposes by virtue of the fact that results accrued by such a method will always be maximal. Degradation of the parent compound to inorganic chloride would be detected if inorganic chloride values were studied separately; however, degradation of the parent compound to chlorine-containing moieties would not be misleading because the total weight of (organic) chloride is interpreted by calculation back to weight of parent compound (dieldrin).

The reliability of the present method was established by analyzing fortified samples, by detailed policing, and by evaluation of efficiency of the various steps in the entire analytical procedure. The total chlorine method as here used appears to be reliable in the presence of as little as 30 micrograms of organic chloride per analytical sample. This quantity, in terms of sample size analyzed, corresponds to 0.1 to 0.2 part per million of dieldrin.

Processing of samples.—The types of samples involved in this study were of the ABC type and the peel and pulp type.

The ABC technique (footnote 9) has been designed to evaluate the rates at which pesticidal molecules penetrate through the various anatomical portions (strata) of citrus peel as well as to afford practical information regarding possibilities of packing house removal of surface residues existing at harvest.

The "A" residue represents material adhering to the outer wax layer of the fruit and for practical purposes may be considered as removable detritis. Removal of this so-called extra-surface residue (Gunther *et al.* 1950) is achieved through washing with a detergent solution. To the field sample packed tightly into a 3-gallon wide-mouthed jar are added 500 milliliters of distilled water and 20 drops of Triton X-45[1]. The jar is tightly capped with waxed paper and a screw cap, then rolled mechanically for 20 minutes. The resultant rinsings are decanted into bottles, which are sealed with waxed paper and a screw cap and stored at 10° C.

After being rinsed throughly with distilled water, the A-treated fruit are dried in a current of air in wire baskets placed in a down-draft hood.

The "B" residue represents material dissolved in or adhering tightly to the actual wax or cuticular layer of the fruit. This represents the so-called cuticular residue (Gunther *et al.* 1950) and is removed by means of a quick solvent laving of individual fruit. Each fruit from the above A-treatment is pierced with an ice pick, held over a 6-inch funnel, and rotated slowly while 15 milliliters of Skellysolve B[2] is sprayed over its surface from a fine-jet graduated cylinder wash bottle operated from the compressed (filtered) air line. These lavings from a given sample are filtered through a tight plug of pre-rinsed cotton, then stored at

[1] A 2-gram sample of our lot of Triton X-45 afforded a nil chloride value when run through the combustion chloride methods as described.

[2] All extraction and equilibration procedures involved the use of Skellysolve B. Although technical grade Skellysolve B contains some chloride (about 18 ppm, as determined by the combustion of the evaporated residue from one liter), most of this chloride can be washed out. For example, liter quantities of Skellysolve B washed four times with chloride-free distilled water afforded combustion values of less than four micrograms of chloride each. This value is well within titration error.

10° C. in screw-cap bottles with waxed paper liners in the caps.

The "C" residue or so-called subcuticular residue (Gunther *et al.* 1950), represents material inside the peel portion of the fruit and is evaluated by means of a one-hour solvent extraction of the tumbling fruit. This procedure leaches to an equilibrium value insecticidal substances from the entire flavedo-albedo layers; within this limit of time the extracting solvent does not penetrate beyond the albedo layer when mature fruit are involved. The A- and B-treated fruit in a given sample are transferred to 3-gallon wide-mouth glass jars, 500 milliliters of Skellysolve B is added to each, and the jars are capped with aluminum foil and a screw cap, then rolled mechanically for one hour. The resultant extract is decanted through pre-rinsed Sharkskin filter paper into bottles, which are sealed with waxed paper and screw caps, then stored at 10° C.

The peel and pulp residues represent material actually penetrated into the total peel and into the pulp, a term applied to that portion of the fruit, including juice, remaining after the peel is removed. The fruits in a given sample are washed manually with soft brushes in warm dilute trisodium phosphate solution, rinsed in distilled water, and dried in wire baskets in a current of air. They are then carefully peeled with the aid of an especially designed "buttonhook" or "crochet-hook" peeler[1] in such a manner that the flavedo-albedo layers are removed cleanly yet the pulp portions are not punctured. After being weighed, the entire mass of peel is thoroughly mixed and one-pound subsamples are withdrawn by quartering. Each subsample is minced (Gunther 1949) in a stainless steel container to a particle size of one-eighth inch or less in the presence of 2 milliliters of Skellysolve B per gram of peel, then equilibrated on a tumbling machine (Gunther & Blinn 1950) for one hour. The resultant supernatant extract is decanted through pre-rinsed Sharkskin filter paper into bottles, which are sealed with waxed paper and screw caps and stored at 10° C.

The peeled fruit are carefully pierced equatorially twice with a No. 15 cork borer with sawtooth edge. From the resulting plugs of pulp the two ends are carefully removed with a clean scalpel, and the thus obtained pulp is pooled and subsampled by quarters to suitable aliquots. These aliquots are minced, tumbled with two milliliters of Skellysolve B per gram for five minutes, when allowed to stand in the sealed stainless steel containers at 10° C. with occasional shaking for 48 hours. The resultant supernatant extract is decanted through pre-rinsed Sharkskin filter paper and stored at 10° C. in bottles capped with waxed paper liners.

Since these extraction operations, except for the B treatment, are equilibration treatments, the amounts of solvents added originally are carefully measured. Thus it is not necessary to secure quantitative separation of emulsions nor to be concerned about hold-up of solvent with coarse, retentive marcs. After equilibration as much of the solvent as can be conveniently recovered is removed by decanting.

Pre-analysis treatment of samples.—The Skellysolve B extract obtained as above is decanted into a French globe-type separatory funnel and washed repeatedly with especially redistilled water[2] until the washings do not precipitate with acidified silver nitrate solution. The sample is then washed twice more and an aliquot is transferred to a Kuderna-Danish apparatus (see Gunther *et al.* 1951) and evaporatively concentrated to about two milliliters. With "C" treatments and with peel treatments, the final Kuderna-Danish volume is about eight milliliters (rind oil). These latter concentrates are transferred quantitatively to petri dishes and allowed to evaporate spontaneously at room temperature under light air draft for 20 hours. The residues in the petri dishes are then transferred quantitatively to Kuderna-Danish evaporators with the aid of Skellysolve B, and again concentrated to about two milliliters.

The aqueous "A" extract is transferred quantitatively to a French separatory

[1] This peeler consists of a 4-inch cylindrical metal handle to the end of which is affixed a slender stainless steel "button hook" or "crochet hook." This hook is sharpened on the inner three-eighths inch edge. In use, the fruit is scored with the hook into 6 or 8 antipodal segments to a depth of about three-eighths inch; the dull outer edge of the hook is then inserted beneath one segment at a polar end, and the segment or flap of peel is pried cleanly off the fruit. With experience, an operator can quickly "feel" the thickness of the peel; with thin-skinned fruit the peeler is angled slightly so as not to embed the hook too deeply into the fruit and perhaps puncture some of the juice cells. A skilled operator can cleanly peel a mature orange in 15 seconds with this device.

[2] Tap distilled water is redistilled from alkaline permanganate solution in an all-glass apparatus.

funnel and extracted with 200-milliliter portions of Skellysolve B. The combined Skellysolve B extracts are then washed with the redistilled water until the detergent has been washed out of the organic solution and further, until the silver nitrate test is negative as above. An aliquot is then transferred to a Kuderna-Danish apparatus and concentrated as above to two milliliters.

While awaiting combustion analysis the Kuderna-Danish concentrates are stored in the Kuderna-Danish tubes stoppered with $\overline{\$}$ plugs.

Combustion analysis of samples.—The combustion technique employed is essentially that described by workers in the Analytical Department, Shell Development Company, Emeryville, California (Agazzi *et al.* 1952), with but minor modifications. The lowest point in the primary absorber has been tapped to allow the absorbing solution to be drained into volumetric flasks, and the adapter leading from the quartz tube to the primary absorber has been rebuilt so that it can be rinsed without disassembling the apparatus. This modified primary absorber unit is diagrammed in figure. 1. The secondary

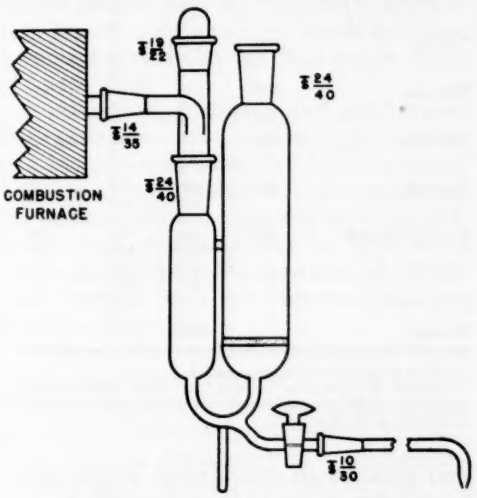

FIG. 1.—Modifications of primary absorber to facilitate withdrawal of trapped combustion products. (See Agazzi *et al.* 1952 for description of original apparatus.)

absorber (Agazzi *et al.* 1952) is used with the especially redistilled water even though chloride has never been detected in this absorber. The air drawn into the apparatus during the first part of the combustion is led through a third packed quartz tube held at 950° to 1000° C. so as to obviate the possibility of contaminated air being drawn into the apparatus.

The preparation of the sample for combustion is as follows: The approximately two milliliters of concentrate remaining in the Kuderna-Danish tube is transferred quantitatively a few drops at a time to a #6 porcelain boat held in a rack especially designed to grasp only a small portion of the handle of the boat.[1] As the Skellysolve B evaporates more of the sample is added until all of the sample and the several washings have been transferred quantitatively to the boat. The boat is allowed to stand two hours in a slow current of air, then it is placed in a vacuum desiccator over concentrated sulfuric acid at a pressure of about 30 millimeters of mercury for an additional hour.

The combustion is performed essentially as described by Agazzi *et al.* (1952).

The analysis of chloride content is performed potentiometrically with the aid of a Beckman Automatic Titrator. The rinsings from the combustion operation are made up to volume in a 100-milliliter volumetric flask. Either the entire flask contents or an aliquot thereof is adjusted to pH 1.0 with 1.5 N chloride-free nitric acid solution on the left-hand unit of the titrator with glass electrode versus calomel-type electrode with a potassium sulfate bridge. Exactly 1.000 ± 0.002 milliliters of 0.01 N sodium chloride solution is added from an automatic burette graduated in 0.02 milliliter units. The total chloride content of the sample is determined by titration with 0.01 N silver nitrate solution, with glass versus giant silver electrodes (Lykken & Tuemmler 1942).

Validation of analytical method.—The combustion technique for determining total organic chlorine in residue studies involves the application of an unusually precise and sensitive analytical method. Indeed, the method is so sensitive that it may be misleading unless provision is made for elaborate replication of both samples and subsamples of plant extractives. Even with this provision, inconsistent results will occasionally be obtained. When properly utilized, the method is

[1] This holder is essential since some oily materials creep up and completely around the boat. This device suspends the boat in air by grasping about 0.25 inch of the handle.

not capable of yielding a negative value.

Adequacy of sampling techniques and of sample replication will be manifest by trends in the data, but not necessarily by the close scrutiny of isolated analytical values. Furthermore, significance may be attached both to the apparent trends and to the detailed but replicated data if certain policing measures are enforced during the accumulation of the residue analyses. The adequacy of these policing measures establishes the reliability of the results.

It is to be borne in mind that the present data represent *maximal* loads of apparent dieldrin on and in citrus fruit under the conditions and practices as specified. It must also be pointed out that all chloride values have been interpreted as *apparent* dieldrin; the assurance that the chlorides encountered arose from intact dieldrin cannot be made. In the present method the inorganic chlorides so abundantly found in plant parts in variable amounts (Bogusch 1945) have been eliminated from consideration. The use of this method would therefore seem to be justified for the present purpose. Consideration of the structure of dieldrin indicates that the ready formation of non-chlorine containing degradation or other metabolic products *in situ* is hardly possible.

A discussion of the pertinent sources of error in the present method must accordingly be limited to the laboratory practices. A critical evaluation of the check-sample variability is not possible with the present data; adequate field sampling techniques—with especial attention to previous spray and other treatment history—must be re-evaluated for this new method because of the apparent occurrence in citrus fruit not treated with dieldrin of small amounts of organic chlorides, although the frequent appearance of perfect check samples suggests that these organic halides may not be naturally-occurring ones. Validation of the laboratory practices will, however, justify the efficiency claims for the method and will also justify scrutiny of the trends apparent in the present data.

That the present data approach maximal may be demonstrated by verification of the efficiency of the method. The establishment of this efficiency then permits a critical examination of the positive sources of error through trace contamination as contributors to inconsistently high values. The elaborate nature of the method favors occasional contaminated analytical samples, but the enforcement of adequate policing operations minimizes the appearance of possible questionable values. The following discussions are accordingly bracketed into efficiency and contamination subject headings.

A. Efficiency.—The stepwise efficiencies of the processing and combustion methods are shown in table 1. Apparent trace contaminations occurred up to the washing stage; all but one of these values are within the titration error and are, therefore, not established as contamination errors. Since the tabulated extraction operations are equilibration operations, a given sample moves progressively from aliquot to sub-aliquot to sub-sub-aliquot,

Table 1.—Effciencies of processing and combustion methods as established for the individual steps involved in a complete blank analysis.

Addendum Stage	Milliliters Skellysolve B Each	Micrograms Dieldrin		Per Cent Recovery
		Added	Found	
"A" jar with detergent	500	0	0	—
		0	0	—
		0	0	—
"C" jar	500	0	1	—
		0	0	—
		0	4	—
Pulp can	908	0	9	—
		0	31	—
		0	6	—
Peel Can	908	0	14	—
		0	0	—
		0	9	—
Washing	500	482	429	89
		482	429	89
		0	0	—
Kuderna-Danish[1]	500	406	426	105
		406	414	102
		203	211	104
		203	205	101
		0	10	—
		0	10	—
Furnace	—	8800[2]	8800	100

[1] Two drops of white oil also added.
[2] Added as crystalline dieldrin; all other fortifications involved the addition of measured volumes of a standard solution of dieldrin in Skellysolve B.

and thus small operational losses of extract solution are of no consequence.

There is no elegant way to determine the efficiency of the first equilibration involved in extracting the dieldrin from the fruit part. The method of marc fortification is subject to criticism on the basis of artificial, localized distribution, and in general affords falsely high efficiencies; the method of successive extractions of marcs from field-treated fruit is a more

realistic approach to efficiency evaluation because it establishes the unit-equilibration amount of extractable material in field-treated fruit parts in relation to the total amount of extractable material present. This efficiency for dieldrin in orange and lemon peel has been established as 85 per cent (average) for one standard equilibration with 2 milliliters of Skellysolve B per gram of minced peel.[1]

The over-all efficiency of the laboratory operations which amounts to 76 per cent may therefore be generalized in table 2.

Table 2.—Summarized over-all efficiency of laboratory operations.

OPERATION	MINIMUM EFFICIENCY
First equilibration (extraction from peel)	85%
Washing to remove inorganic chlorides	89
Kuderna-Danish evaporation	100
Combustion	100

B. Contamination.—The sources of contamination prior to the washing operation ordinarily will involve contamination of the equipment and solvents with organic halides. Contamination of this sort can be policed only by frequently submitting known solutions and check solvents, to be processed through the entire series of operations.

Contamination during and after washing operations can involve both organic and inorganic halides. With the required number of manipulations, an occasional contaminated sample should be expected. Such contaminations can be kept to a minimum by frequent insertion of checks and knowns, and by rigorous policing regimens.

Gross contamination could occur from boats improperly burned or cleaned. To minimize this error, the combustion boats are cleaned between each run as follows: The boat is immersed in dichromate-sulfuric acid cleaning solution at 100° C. for 12 hours, then rinsed thoroughly, and finally with the especially redistilled water, then burned at white heat for one to two hours. The boats and other apparatus used are never touched with the fingers but are handled only with special tongs and supports designed for the purpose. In order to demonstrate the lack of boat contamination in the present study, attention is drawn to table 3,

Table 3.—Demonstration of negligible boat contamination as determined by the lack of consistent apparent dieldrin residues from sequential analyses of miscellaneous lemon samples.

BOAT 6			BOAT 25		
Code	Type of Sample	Micrograms Dieldrin	Code	Type of Sample	Micrograms Dieldrin
1	Pulp	30	14	"B" Strip	0
2	Peel	640	15	"C" Strip	550
3	"B" Strip	0	16	"B" Strip	172
4	Pulp	20	17	"B" Strip	0
5	"B" Strip	30	18	"B" Strip	142
6	"B" Strip	1596	19	"B" Strip	348
7	"B" Strip	644	20	"A" Strip	396
8	"B" Strip	0	21	"A" Strip	60
9	"C" Strip	163	22	Peel	90
10	"C" Strip	1587			
11	"A" Strip	456			
12	"A" Strip	2288			
13	"A" Strip	34			

wherein the apparent dieldrin values from all the samples burned in each of two boats are recorded. It is evident that even when a boat contained 2000 micrograms of apparent dieldrin, any contamination resulting was not transferred to the next sample in a consistent manner.

As miscellaneous policing practices may be included the following: (1) All equipment involved before the washing operation is rinsed thoroughly with Skellysolve B just prior to use; (2) all equipment involved after the washing operation is rinsed thoroughly with the especially redistilled water just prior to use; (3) all rubber tubing on the furnace end of the combustion apparatus is rinsed each day with the especially redistilled water; (4) all reagents are drawn from stoppered bottles with automatic pipettes; (5) all titrating solutions are stored in the reservoirs of, and dispensed from, all-glass automatic burettes; (6) the silver nitrate solution is standardized every day; and (7) all wash bottles are mechanically operated.

RESULTS.—During the course of these studies information was developed on the use of dieldrin sprays to control citrus thrips with respect to (1) dosage, (2) comparison of wettable powder and emulsifiable concentrate formulations, (3) effect of adding sugar, (4) compatibility with zinc-containing nutritional supplements and certain pesticides, (5) fruit residues,

[1] This same average per cent efficiency of extraction (equilibration) also applies to DDT and parathion (Gunther and Blinn 1950). Compound 88R (Gunther *et al.* 1951), and Compound K-6451 and EPN (unpublished data). It could be interpreted as the adsorption efficiency of the ground peel under these conditions. Benzene is used with DDT and parathion; Skellysolve B is used with the other pesticides mentioned. The most elaborate evaluation of this efficiency was made with DDT, with an efficiency range of 78 to 92 per cent.

Table 4.—Control of citrus thrips to prevent fruit scarring of oranges and grapefruit with dieldrin sprays applied at time of petal fall with spray-duster at rate of 100 gallons per acre. Effect of dosage, formulation, and addition of sugar, certain pesticides, or zinc-containing nutritional supplements.

Grove No., Location, Variety, and Date of Application; Treatments and Amts./100 Gals. of Spray	Lbs. Dieldrin per Acre	Per Cent Fruit Scarred[1]
1. Lemon Cove; navel orange; 5/14/51		
(1) 1.25 lbs. 20% dieldrin W	0.25	13.5
(2) 2.5 lbs. 20% dieldrin W	0.5	0.8
(3) Same as (2)+20 lbs. 15% Compound 88R[2]W	0.5	8.5
(4) Same as (2)+20 lbs. 40% Compound R-242[2] W	0.5	2.0
(5) 4 lbs. 50% DDT W (standard)	—	4.4
(6) Untreated check	—	90.1
2. Porterville; navel orange; 5/7/51		
(7) 1 lb. 25% dieldrin W	0.25	0.0
(8) 2 lbs. 25% dieldrin W	0.5	0.4
(9) 4 lbs. 25% dieldrin W	1.0	0.2
(10) Same as (8)+10 lbs. ZnO	0.5	0.2
(11) Same as (8)+20 lbs. $ZnSO_4$+10 lbs. soda ash	0.5	0.2
(12) 1 qt. dieldrin E (1 lb. dieldrin/gal.)	0.25	2.6
(13) 2 qts. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.4
(14) 1 gal. dieldrin E (1 lb. dieldrin/gal.)	1.0	0.0
(15) 7 lbs. 14% nicotine conc.[4]+4 lbs. sugar (stand.)	—	28.4
(16) 8 lbs. 50% DDT W (2X standard)	—	37.9
3. Terra Bella; navel orange; 5/11/51		
(17) 1 lb. 25% dieldrin W	0.25	0.0
(18) 2 lbs. 25% dieldrin W	0.5	0.4
(19) 4 lbs. 50% DDT W (standard)	—	19.9
4. Indio; grapefruit; 4/7/49		
(20) 1 lb. 25% dieldrin W	0.25	1.1
(21) 2 lbs. 25% dieldrin W	0.5	0.4
(22) 8 lbs. sabadilla prep.[5]+6 lbs. sugar (stand.)	—	4.8
5. Porterville; navel orange; 5/17/49		
(23) 2 lbs. 25% dieldrin W	0.5	0.0
(24) Same as (23)+4 lbs. sugar	0.5	0.0
(25) 7 lbs. 14% nicotine conc.[4]+4 lbs. sugar (stand.)	—	13.1
(26) 4 lbs. 50% DDT W (standard)	—	26.6
(27) 6 lbs. sabadilla prep.[5]+6 lbs. sugar (stand.)	—	7.4
6. Corona; navel orange; 7/9/49		
(28) 4 lbs. 25% dieldrin W	1.0	3.2
(29) Same as (28)+4 lbs. sugar	1.0	2.5
(30) 4 lbs. tartar emetic+4 lbs. sugar (standard)	—	35.1

[1] A treatment was considered commercially effective if less than 5.0 per cent of the fruit were scarred.
[2] 2-(*p-tert.*-butylphenoxy)isopropyl 2-chloroethyl sulfite. Naugatuck Chemical Div., United States Rubber Co., New York, N. Y.
[3] *p*-Chlorophenyl phenylsulfone. Stauffer Chemical Co., New York, N. Y.
[4] Tobacco By-Products and Chemical Corp., Richmond, Va.
[5] Contains 1.90% sabadilla alkaloid complex. Leffingwell Chemical Co., Whittier, Calif.

and (6) effect on beneficial insects under field conditions.

Dosage.—Results with treatments of 0.25, 0.5, and 1.0 pound of dieldrin per acre for the prevention of fruit scarring on navel oranges and grapefruit are summarized in table 4, and for the protection of new vegetative growth on lemons in table 5.

Applications made to prevent fruit scarring in groves having moderately heavy thrips populations (Table 4, Groves 2, 3, 4, 5) showed only slight differences among the three dosage levels; all dieldrin treatments were more effective than the standard treatments. The effectiveness of dieldrin in Groves 2, 3 and 5 (Table 4) is of noteworthy, practical importance, since the thrips in these groves have apparently developed resistance to the standard DDT treatment. Particularly evident is Grove 2 (Table 4), where twice the normal standard DDT dosage failed to give satisfactory commercial control. In one grove where thrips scarred the fruit much later in the summer than usual (Table 4, Grove 6) dieldrin treatments applied in July gave commercial control whereas the standard tartar emetic-sugar treatment was relatively ineffective.

For the protection of new growth on lemons, treatments of 0.25 and 0.5 pound of dieldrin per acre applied as wettable powder suspensions were equally effective 8 weeks after application; applied as emulsifiable concentrate emulsions the 0.25-pound and 0.5-pound dosages were equally effective after 8 weeks, but slightly less effective than comparable dosages applied as wettable powder sprays (Table 5, Grove 1). In this grove the standard sabadilla-sugar treatment lost its effectiveness in 6 to 8 weeks. In all groves the 0.5-pound dosage of dieldrin per acre remained effective longer than the standard tartar emetic-sugar, nicotine-sugar, DDT, and sabadilla-sugar treatments. In most groves having moderately high populations of thrips (Table 5, Groves 1, 4, 5—1st application, 6, 7, 8, 9) dieldrin applied at the rate of 0.5 pound per acre was effective for 8 or more weeks, whereas the standard treatments usually lost their effectiveness in less than 6 weeks; in groves having relatively high populations of thrips (Table 5, Groves 2, 3, 5—2nd application) treatments of 0.5 pound of dieldrin per acre remained effective for 4 to 6 weeks while standard treatments were effective from 2 to 4 weeks.

Comparison of wettable powder and emulsifiable concentrate formulations.—When applied at the dosage of 0.5 pound of dieldrin per acre, wettable powder and emulsifiable concentrate formulations were approximately equally effective in the commercial control of citrus thrips (Table 4, Grove 2; Table 5, Groves 1, 3, 4). In one experiment (Table 4, Grove 2) the dosage of 0.25 pound of dieldrin per acre was slightly more effective as a wettable powder than as an emulsifiable

Table 5.—Control of citrus thrips to protect new growth on lemons with dieldrin sprays applied with spray-duster at the rate of 100 gallons per acre per application. Effect of dosage, formulation, and addition of sugar or certain pesticides.

GROVE NO., LOCATION, AND DATE(S) OF APPLICATION; TREATMENTS AND AMTS./100 GALS OF SPRAY	LBS. DIELDRIN/ ACRE/APPL.	AVERAGE NO. THRIPS PER TERMINAL[1] (Wks. After Application)				
1. San Fernando; 5/31/51		(4)		(6)		(8)
(1) 1.25 lbs. 20% dieldrin W	0.25	0.20		0.02		0.08
(2) 2.5 lbs. 20% dieldrin W	0.5	0.28		0.04		0.06
(3) Same as (2)+4 lbs. 15% Compound 88R W[2]	0.5	0.12		0.02		0.06
(4) Same as (2)+4 lbs. 50% Compound K-6451 W[3]	0.5	0.14		0.00		0.08
(5) Same as (2)+4 lbs. 40% Compound K-1875 W[4]	0.5	0.14		0.00		0.10
(6) 1 qt. dieldrin E (1 lb. dieldrin/gal.)	0.25	0.20		0.02		0.32
(7) 2 qts. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.16		0.00		0.24
(8) 1.5 gals. sabadilla prep.[5]+5 lbs. sugar (stand.)	—	0.14		0.10		2.76
		1st Application		2nd Application		
2. Alta Loma; 7/6 & 8/16/49		(2)	(4)	(2)	(4)	
(9) 2 lbs. 25% dieldrin W	0.5	0.00	0.49	0.11	0.13	
(10) 8 lbs. 50% DDT W (standard)	—	0.10	0.72	0.00	0.35	
(11) 8 lbs. sabadilla prep.[6]+6 lbs. sugar (stand.)	—	0.22	1.20	0.29	0.60	
3. San Fernando; 6/8/51		(2)	(4)	(6)	(8)	
(12) 2 lbs. 25% dieldrin W	0.5	0.04	0.02	0.64	6.06	
(13) 2 qts. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.12	0.04	0.52	6.04	
(14) 8 lbs. 50% DDT W (standard)	—	0.26	0.24	1.56	9.94	
		1st Application		2nd Application		
4. San Fernando; 6/4 & 8/15/51		(6)	(8)	(2)	(4)	
(15) 2 lbs. 25% dieldrin W	0.5	0.00	0.34	0.10	0.06	
(16) 2 qts. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.06	0.28	0.06	0.12	
(17) 1 gal. sabadilla prep.[5]+5 lbs. sugar (stand.)	—	0.14	2.90	0.18	0.28	
		1st Application		2nd Application		
5. San Fernando; 5/9 & 8/16/50		(10)		(2)	(4)	(6)
(18) 2 lbs. 25% dieldrin W	0.5	0.38		0.39	0.36	0.60
(19) Same as (18)+2 lbs. sugar	0.5	0.38		0.32	0.18	0.80
(20) Same as (18)+6 lbs. 25% EPN[7] W	0.5	0.10		0.38	0.22	0.78
(21) 7 lbs. 14% nicotine conc.[8]+4 lbs. sugar (stand.)	—	1.20		0.92	2.20	3.60
(22) 8 lbs. sabadilla prep.[6]+4 lbs. sugar (stand.)	—	0.60		1.20	1.70	1.80
6. Alta Loma; 8/15/50		(2)	(4)	(8)		
(23) 2 lbs. 25% dieldrin W	0.5	0.10	0.04	0.24		
(24) Same as (23)+4 lbs. sugar	0.5	0.08	0.06	0.16		
(25) Same as (23)+20 lbs. 15% Compound 88R[2] W	0.5	5.78	0.04	0.24		
(26) Same as (23)+10 lbs. 50% Compound K-6451[3] W	0.5	0.54	0.04	—		
(27) 1 qt. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.16	0.00	0.18		
(28) Same as (27)+4 lbs. sugar	0.5	0.52	0.22	0.22		
(29) 6⅔ lbs. 75% DDT W (standard)	—	0.16	0.20	0.36		
(30) 6 lbs. sabadilla prep.[6]+6 lbs. sugar (stand.)	—	0.18	0.12	0.60		
7. San Fernando; 6/4/51		(6)	(8)	(12)		
(31) 2 lbs. 25% dieldrin W	0.5	0.00	0.18	0.22		
(32) Same as (31)+5 lbs. 15% Compound 88R[2] W	0.5	0.02	0.22	0.30		
(33) Same as (31)+5 lbs. 50% Compound K-6451[3] W	0.5	0.02	0.10	0.52		
(34) Same as (31)+6 lbs. 40% Compound R-242[9] W	0.5	0.00	0.18	0.98		
(35) 2 qts. dieldrin E (1 lb. dieldrin/gal.)	0.5	0.02	0.48	0.70		
(36) 6 lbs. 50% DDT W (standard)	—	0.04	1.08	1.36		

Table 5—(Continued)

GROVE NO., LOCATION, AND DATE(S) OF APPLICATION; TREATMENTS AND AMTS./100 GALS OF SPRAY	LBS. DIELDRIN/ ACRE/APPL.	AVERAGE NO. THRIPS PER TERMINAL[1] (WKS. AFTER APPLICATION)	
		1st Application	2nd Application
8. San Fernando; 5/9 & 8/15/50		(10)	(2)
(37) 4 lbs. 25% dieldrin W	1.0	0.28	0.22
(38) 6 lbs. 50% DDT W (standard)	—	0.34	1.60
9. San Fernando; 5/10/50		(9)	
(39) 4 lbs. 25% dieldrin W	1.0	0.22	
(40) Same as (39)	1.0	0.30	
(41) 7 lbs. 14% nicotine conc.[8]+4 lbs. sugar (stand.)	—	1.10	

[1] A treatment was considered commercially effective so long as the thrips population averaged less than 0.50 thrips per terminal.
[2] 2-(*p-tert.*-Butylphenoxy)isopropyl 2-chloroethyl sulfite. Naugatuck Chemical Div., United States Rubber Co., New York, N.Y.
[3] *p*-Chlorophenyl-*p*-chlorobenzenesulfonate. The Dow Chemical Co., Midland, Mich.
[4] Bis-(*p*-chlorophenoxy)methane. The Dow Chemical Co., Midland, Mich.
[5] Contains 0.5% sabadilla alkaloid complex. Leffingwell Chemical Co., Whittier, California.
[6] Contains 1.90% sabadilla alkaloid complex. Leffingwell Chemical Co., Whittier, California.
[7] Ethyl *p*-nitrophenyl thionobenzene phosphonate. E. I. duPont de Nemours & Co. (Inc.,)Wilmington, Del.
[8] Tobacco By-Products and Chemical Corp., Richmond, Va.
[9] *p*-Chlorophenyl phenylsulfonone. Stauffer Chemical Co., New York, N. Y.

Table 6.—Harvest residues of organic chloride (as dieldrin) in peel and pulp[1] in navel oranges and lemons treated with commercial-type dieldrin sprays for the control of citrus thrips. Navel oranges were treated at (1) time of petal fall (May) to prevent fruit scarring and/or (2) in late summer (August) or September) to protect new growth. Lemons were treated twice during summer to protect new growth Navel oranges were sampled October 15, 1951, and the lemons September 24, 1951, for residue analyses. Applications were made with spray-duster at rate of 100 gallons per acre per application.

GROVE, LOCATION AND VARIETY; TREATMENTS AND AMOUNTS PER 100 GALLONS OF SPRAY	APPLICATION DATE(S)	LBS. DIELDRIN ACRE/APPL.	PPM[2] DIELDRIN IN FRUIT	
			Peel	Pulp[1]
1. Ivanhoe; navel orange				
1 qt. dieldrin E (1 lb. dieldrin/gal.)	5/12/51	0.25	0.5	0.0
1 lb. 25% dieldrin W	9/13/15	0.25	0.6	0.0
(2 treatments)				
1st—2 lbs. 25% dieldrin W	5/12/51	0.5		
2nd—1 lb. 25% dieldrin W	9/13/51	0.25	0.2	0.1
2. Porterville; navel orange				
2 lbs. 25% dieldrin W	5/7/51	0.5	0.2	0.0
2 qts. dieldrin E (1 lb. dieldrin/gal.)	5/7/51	0.5	0.3	0.5
2 lbs. 25% dieldrin W	8/29/51	0.5	0.5	0.4
2 qts. dieldrin E (1 lb. dieldrin/gal.)	8/29/51	0.5	0.3	0.0
Check: 12 lbs. 25% EPN[3]				
1 gal. sabadilla prep.[4]+4 lbs. sugar	8/29/51	—	0.3	0.4
3. Terra Bella; navel orange				
2 lbs. 25% dieldrin W	5/11/51	0.5	0.2	0.2
Check: 6 lbs. 25% EPN W	5/11/51			
4 lbs. 25% EPN W	8/28/51	—	0.0	0.0
Check: 4 lbs. 50% DDT W	5/11/51			
6 lbs. 25% parathion W	8/28/51	—	0.0	0.0
4. San Fernando; lemon				
(2 treatments)				
2 lbs. 25% dieldrin W	6/8 & 8/15/51	0.5	1.0	0.2
2 qts. dieldrin E (1 lb. dieldrin/gal.)	6/8 & 8/15/51	0.5	1.1	0.3
5. San Fernando; lemon				
(2 treatments)				
2 lbs. 25% dieldrin W	6/8 & 8/15/51	0.5	0.6	0.2
2 qts. dieldrin E (1 lb. dieldrin/gal.)	6/8 & 8/15/51	0.5	1.3	0.3
6. San Fernando; lemon				
Check: 2 treatments of nicotine-sugar[5]				
(June & August)		—	0.6	0.4

[1] Pulp refers to portion of fruit, including juice, remaining after peel is removed.
[2] Based on fresh weight of part concerned.
[3] Ethyl *p*-nitrophenyl thiobenzene phosphonate. E. I. duPont de Nemours & Co. (Inc.), Wilmington, Del.
[4] Contains 0.5% sabadilla alkaloid complex. Leffingwell Chemical Co., Whittier, California.
[5] Commercial treatment (1 qt. nicotine sulfate+4 lbs. sugar/100 gal./acre/application).

Table 7.—Penetration and persistence of organic chloride (as dieldrin)) in ABC[1] strata of peel from lemons sprayed under field conditions with a heavy dosage[2] of dieldrin. Treatments applied July 16, 1951 with high pressure sprayer in a standard thorough coverage manner at approximately 20 gallons per tree.

Materials and Amounts per 100 Gallons of Spray	Lbs. Dieldrin per Acre	Elapsed Days	Average ppm.[3] Dieldrin in Peel			
			A	B	C	Total
2 lbs. 25% dieldrin W	9.0	0	1.4	0.0	0.3	1.7
		1	0.6	0.0	0.6	1.2
		3	0.2	0.0	0.3	0.5
		7	0.5	0.1	0.5	1.1
		15	0.2	0.0	0.4	0.6
		31	0.1	0.1	0.2	0.4
2 qts. emulsifiable concentrate (1 lb. dieldrin/gallon)	9.0	0	1.1	0.1	0.6	1.8
		1	0.2	0.0	0.8	1.0
		3	0.1	0.0	0.6	0.7
		7	0.1	0.0	0.4	0.5
		15	—	0.0	0.4	—
		31	0.0	0.1	0.3	0.4
Untreated check	—	0	0.1	0.0	0.0	0.1
		1	0.0	0.0	0.1	0.1
		3	0.0	0.0	0.2	0.2
		7	0.0	0.1	0.1	0.2
		15	—	0.0	0.2	—
		31	0.0	0.0	0.1	0.1

[1] A—residue adhering to wax layer; B—residue within wax layer; C—residue penterated below wax layer.
[2] This dosage was applied specifically for residue studies and was in excess of that required to control citrus thrips.
[3] Based on fresh weight of entire fruit.

concentrate formulation in preventing fruit scarring.

Effect of adding sugar.—The addition of 2 to 4 pounds of sugar per 100 gallons of spray to dieldrin sprays was of no practical benefit when dieldrin was applied at the rate of 0.5 pound per acre (Table 4, Grove 5; Table 5, Groves 5, 6, 9) or 1.0 pound per acre (Table 4, Grove 6; Table 5, Grove 9).

Compatibility with zinc-containing nutritional supplements and certain pesticides.—Certain experiments were conducted in which commercial treatments of zinc oxide and zinc sulfate, applied for control of zinc deficiency in the trees, were added to dieldrin sprays applied for control of citrus thrips. Typical results are shown in table 4 (Grove 2). There is no evidence that either zinc compound as used interfered with the effectiveness of dieldrin sprays in controlling citrus thrips to prevent fruit scarring.

Other experiments involved the combining of pesticides (Compounds 88R,[1] K-6451,[2] K-1875,[3] R-242,[4] or EPN[5]) with dieldrin sprays. When added at the rate of 20 pounds of 15 per cent wettable powder per 100 gallons of spray, Compound 88R apparently reduced the effectiveness of dieldrin in controlling citrus thrips to prevent fruit scarring (Table 4, Grove 1) on navel oranges, and to protect new growth on lemons (Table 5, Grove 6). The addition of 20 pounds of 40 per cent Compound R-242 wettable powder or 10 pounds of 50 per cent Compound K-6451 wettable powder per 100 gallons of spray also reduced the effectiveness of dieldrin (Table 4, Grove 1; Table 5, Grove 6) but to a less extent than did Compound 88R. This reduction in effectiveness of dieldrin sprays for thrips control by the addition of the above miticides is not clearly understood. It may be the result of the presence of relatively large amounts of suspended solids in the sprays masking the effectiveness of dieldrin rather than chemical incompatibility since the addition of lesser amounts of compounds 88R, K-6451, K-1875, R-242, or EPN apparently did not reduce the effectiveness of dieldrin in other experiments (Table 5, Groves 1, 5, 7).

[1] 2-(*p-tert.*-butylphenoxy) isopropyl 2-chloroethyl sulfite. Naugatuck Chemical Division, United States Rubber Co., New York, N. Y.
[2] *p*-chlorophenyl-*p*-chlorobenzene sulfonate. The Dow Chemical Co., Midland, Mich.
[3] Bis-(*p*-chlorophenoxy)-methane. The Dow Chemical Co., Midland, Mich.
[4] *p*-chlorophenyl phenylsulfone. Stauffer Chemical Co., New York, N. Y.
[5] Ethyl *p*-nitrophenyl thiobenzene phosphonate. E. I. du-Pont de Nemours & Co. (Inc.), Wilmington, Del.

Table 8.—Effect of various treatments applied for the control of citrus thrips on grapefruit in the Coachella Valley on the population of vedalia, the ladybird predator of cottony-cushion scale. Applications made with spray-duster at the rate of 100 gallons per acre on April 20, 1951.

Materials and Amounts per 100 Gallons of Spray	Lbs. Dieldrin per Acre	Vedalia Population Counts[1]		
		Date	Living	Pupal Cases
2 lbs. 25% dieldrin W	0.5	4/30/51	0.1	—
		5/16/51	3.6	—
		6/6/51	13.5	10.3
		6/20/51	38.0	29.9
		7/5/51	0.6	41.8
2 qts emulsifiable concentrate (1 lb. dieldrin/gallon)	0.5	4/30/51	1.6	—
		5/16/51	1.0	—
		6/6/51	10.9	14.7
		6/20/51	19.6	30.6
		7/5/51	1.5	43.2
8 lb. 50% DDT W (standard)	—	4/30/51	0.0	—
		5/16/51	0.0	—
		6/6/51	0.2	5.4
		6/20/51	14.0	2.5
		7/5/51	3.0	15.9
1 gal. Sabadilla Prep.[2]+5 lbs.sugar(standard)	—	4/30/51	1.1	—
		5/16/51	3.3	—
		6/6/51	9.1	5.5
		6/20/51	36.8	22.7
		7/5/51	1.3	36.9

[1] Counts on 4/30/51 and 5/16/51 are average number of living vedalia per 10 cottony-cushion scale colonies; later counts are average number of living vedalia or pupal cases per tree observed during a 2-minute search.
[2] Contains 0.5% sabadilla alkaloid complex. Leffingwell Chemical Co., Whittier, California.

Fruit residues.—In table 6 are shown the harvest residues of organic chloride (as dieldrin) in the peel and pulp of fully ripe navel oranges and lemons resulting from commercial-type applications of dieldrin sprays applied for the control of citrus thrips. The amounts of apparent dieldrin ranged from 0.2 to 0.6 p.p.m. in the peel and from 0.0 to 0.5 p.p.m. in the pulp of navel oranges treated with dieldrin in May or August or September (Table 6, Groves 1, 2, 3) when they were harvested in October; in comparison, fruit not treated with dieldrin (Table 6, Groves 2, 3) the range was from none to 0.3 p.p.m. in the peel and from none to 0.4 p.p.m. in the pulp; this results in a *net average* of 0.3 p.p.m. in the peel and 0.0 p.p.m. in the pulp of treated oranges.

On lemons treated with dieldrin sprays in June and again in August (Table 6, Groves 4, 5) the amounts of apparent dieldrin ranged from 0.6 to 1.3 p.p.m. in the peel and from 0.2 to 0.7 p.p.m. in the pulp of fruit harvested approximately six weeks after the second application; in an adjacent grove not receiving a dieldrin treatment (Table 6, Grove 6) an average of 0.6 p.p.m. apparent dieldrin was found in the peel and 0.4 p.p.m. in the pulp; the *net average* amounts to 0.4 p.p.m. in the peel and 0.0 p.p.m. in the pulp of the treated fruit.

On the basis of these analytical values it would appear that 1 or 2 treatments of dieldrin applied at the rate of 0.5 pound per acre per application will result in an average of less than 0.5 p.p.m. apparent dieldrin in the peel (based on fresh weight of peel) and no detectable amounts in the pulp of fruit harvested at least 30 days after the last application.

Studies were also made of the penetration and persistence of dieldrin residues in the ABC (see footnote 9) peel strata of lemons following thorough-coverage spray treatments of dieldrin applied over fully ripe fruit. These sprays contained 0.5 pound of dieldrin, either as a wettable powder or as an emulsifiable concentrate formulation, per 100 gallons. Applications were made at the rate of 20 gallons per tree, which amounted to approximately 9.0 pounds of dieldrin per acre. This quantity is considerably more than the 0.5 pound dosage required for the commercial control of citrus thrips and was used for ABC studies only. The fruits were sampled for analyses immediately after application when the spray residues had dried, and 1, 3, 7, 15, and 31 days later. The results, which are summarized in table 7, show that dieldrin penetrated fairly rapidly into the inner portion (C) of the peel for both formulations; the emulsifiable concentrate formulation was somewhat faster in this regard than the wettable powder as is shown by the residue values at 0, 1, and 3 days after application. Apparently dieldrin does not accumulate in the wax layer of the fruit (B) as only trace amounts of dieldrin were detected in this layer on any of the dates sampled. The loss of total dieldrin ($A+B+C$) was rapid, amounting to more than 75 per cent within 31 days after the treatments were applied. There was no appreciable difference between the formulations in this regard. The background chloride (calculated as dieldrin) in the untreated fruit ranged from 0.0 to 0.2 p.p.m. in the different peel strata.

Effect on beneficial insects.—There was an opportunity in these studies to observe the effect of dieldrin applications on the population of vedalia, *Rodolia cardinalis* (Muls.), the ladybird predator of cottony-cushion scale, *Icerya purchasi* Mask., in a grapefruit grove that had a fairly heavy

population of this scale at the time of treatment. Dieldrin was applied at the rate of 0.5 pound per acre at time of petal fall to prevent fruit scarring at which time a few scattered vedalia were feeding on the cottony-cushion scale. Observations were made throughout the summer on the population of vedalia and the results are summarized in table 8. The first records taken on April 30, ten days after the treatments were applied, showed living vedalia in both the dieldrin-treated plots and in the plots treated with sabadilla-sugar. In contrast no living vedalias were found in the plot receiving the DDT treatment until June 6, approximately 6 weeks after the application. The vedalia pupal case records, which afford a measure of the numbers of vedalias able to complete their development on the trees counted, showed only slight differences between dieldrin-treated and sabadilla-treated plots; however, the number of pupal cases found in the DDT-treated plot was relatively low. It is therefore apparent that dieldrin sprays as applied in this grove were less detrimental to vedalia than was the standard DDT treatment. Observations in other groves treated with similar sprays of dieldrin indicate this insecticide does not greatly interfere with the activity of vedalia.

The population of soft scale, *Coccus hesperidum* (L.), was also evaluated in groves treated with dieldrin to determine whether such treatments result in abnormally high populations of this pest through elimination of its parasites such as occurs in certain groves following treatments of parathion (Bartlett & Ewart 1951, Elmer *et al.* 1951). Throughout these studies there was no evidence of the development of heavy populations of soft scale following experimental field applications of dieldrin for control of citrus thrips.

SUMMARY.—Results obtained over a 3-year period with dieldrin sprays applied for the control of citrus thrips, *Scirtothrips citri* (Moult.), to prevent fruit scarring of navel oranges and grapefruit, and to protect new vegetative growth on lemons are presented.

It was found that a dosage of 0.5 pound of dieldrin per acre applied in sprays at the rate of 100 gallons per acre with a spray-duster prevented fruit scarring in groves having heavy thrips populations and in groves where citrus thrips had apparently become resistant to DDT. At this dosage level there was no appreciable difference between emulsifiable concentrate and wettable powder formulations of dieldrin. At 0.25 pound of dieldrin per acre commercial thrips control was obtained in groves having moderate but not heavy populations of thrips. There was no advantage of 1.0 pound over 0.5 pound of dieldrin per acre in the control of citrus thrips.

For protection of new growth on lemons 0.5 pound of dieldrin per acre afforded commercial control for 8 weeks or longer in groves having light or moderate thrips populations throughout the summer, and from 4 to 6 weeks in groves where heavy thrips populations occurred. In comparison, standard treatments of DDT, nicotine-sugar, sabadilla-sugar, and tartar emetic-sugar remained effective for 4 to 6 weeks in groves having light to moderate populations, and from 2 to 4 weeks in groves having heavy populations.

The addition of sugar did not improve the effectivensss of dieldrin sprays in controlling citrus thrips.

It was found that commercial dosages of zinc oxide or zinc sulfate, applied for zinc deficiency in the trees, could be added to dieldrin sprays without reducing the effectiveness of the dieldrin. However, the addition of 20 pounds of 15 per cent Compound 88R wettable powder, or 20 pounds of 40 per cent Compound R-242 wettable powder, or 10 pounds of Compound K-6451 per 100 gallons of spray apparently reduced the effectiveness of dieldrin sprays. Reasons for this apparent reduction in effectiveness are not understood but the presence of relatively large amounts of solid materials in suspension in the sprays may have masked the toxicity of dieldrin to citrus thrips; there is evidence for this explanation rather than for chemical incompatibility since smaller amounts of the above miticides as well as other pesticides, including Compound K-1875 and EPN did not produce this effect when added to dieldrin sprays in other experiments.

Residues of dieldrin in fruit were determined by means of a total chlorine method described in detail, that permitted determination of microgram quantities of dieldrin residues with a sensitivity of 0.1 to 0.2 part per million. This method involved the micro-combustion technique for the quantitative determination of

organic chlorides and was adapted for residue studies of dieldrin in citrus extractives. Inorganic chlorides were eliminated by water washing of the organic solvent extract mixture, and the final extractives were burned at 1000° C. in a stream of oxygen to CO_2, H_2O, and the hydrogen halide which was then determined potentiometrically.

Harvest residues in navel oranges, sampled in October, which had been treated with 0.5 pound of dieldrin per acre in May or August or September amounted to a net average of 0.3 p.p.m. apparent dieldrin in the peel and 0.0 p.p.m. in the pulp over amounts found in untreated fruit. Similarly, lemons treated with the same dosage in June and again in August had a net average of 0.4 p.p.m. apparent dieldrin in the peel and 0.0 p.p.m. in the pulp when harvested six weeks after the second application.

In *ABC* studies to determine the penetration and persistence of dieldrin residues in the peel of lemons it was found that penetration of dieldrin from the surface (*A*) to the inner portion (*C*) of the peel was more rapid for an emulsifiable concentrate than for a wettable powder formulation. There was little, if any, accumulation of dieldrin in the wax layer (*B*) of the fruit. The loss of total dieldrin (*A*+*B*+*C*) amounted to more than 75 per cent within 31 days after application, with no appreciable difference between formulations in this respect.

Dieldrin sprays applied for the control of citrus thrips did not interfere with vedalia, *Rodolia cardinalis* (Muls.), the ladybird predator of cottony-cushion scale, *Icerya purchasi* Mask., as does DDT. There was no evidence that populations of soft scale, *Coccus hesperidum* (L.), increased abnormally as a result of dieldrin eliminating its parasites.

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Biology and Control of the Imported Fire Ant in Mississippi

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The imported fire ant, *Solenopsis saevissima* var. *richteri* Forel, has spread to many parts of the southeastern United States since its introduction in the vicinity of Mobile, Alabama, since the turn of the century. It is a rather spectacular pest due to its mound building and extremely vicious stinging habits. For these reasons people in infested areas have pressed for recommendations for its control.

Information in this paper covers experiments and observations in the vicinity of Artesia, Mississippi, during 1949 and 1950. This infested area was roughly 15 miles square in 1949. The soil is predominately a heavy black clay underlaid with lime rock. The land was largely in pasture, meadow, and hardwood forest, with some row cropping.

The degree of infestation by the imported fire ant was correlated with the land use. Very few colonies were found in

the hardwood forests or the meadows which were predominantly Johnson grass, while the heaviest concentrations of colonies were found in the pastures where the sod was largely paspalum or Bermuda grass and often clovers. Rather heavy infestations were found in the rowcrop land where cotton, corn or sorghum was grown.

During this investigation there was only one report of the ants invading a home, although mounds were frequently found in dooryards. Parents of small children were particularly concerned about these infestations, because of the danger of severe stinging. When a mound is disturbed, thousands of ants may swarm out and attack the intruder, and stings often fester and take several days to heal. Numerous complaints of stinging were heard from field workers, particularly during cotton harvest. One case was reported of a field worker seeking the aid of a doctor.

The most serious damage done by the imported fire ant is the building of very large mounds. The mounds, which are often reinforced and camouflaged by grass growing in them, are detrimental to farm machinery. This is particularly true of mowing machines and combines used in pastures.

BIOLOGY.—The mounds vary in size up to about 3 feet in diameter and height, but most mounds measure about 18 inches. The mounds offer a gradient of temperature and humidity for brood rearing and during wet weather, they furnish better drained galleries for the ants. The mounds tend to be taller on low land than on higher, better drained soil, and during dry weather, the mounds are built flatter than in wet weather. Wherever it is possible, colonies move to drier ridges such as fence rows, terraces, pond dams, ditch banks, stumps, or road banks. New colonies are usually established, however, on wet natured land. Population pressure seems to limit the large colonies to a spacing of about 30 to 40 feet.

The ants may change the location of the mounds quite often. One colony is known to have constructed three mounds in twenty-four hours. Every colony in a locality may change the location of their mounds in a single day, and then as suddenly reoccupy the old sites.

There are usually five or six tunnels radiating from each mound, at a depth of about one-quarter inch. Tunnels over 80 feet long have been traced with numerous branches. Many of these structures are more or less permanent, but temporary ones may be constructed to a food source in a matter of hours. Ordinarily very few of the ants may be seen on the surface of the ground.

A study of food habits revealed that this ant is practically omnivorous. Seeds and juices of many plants are eaten, and fragments of leaves and stems are used to patch the mound during dry weather. They are known to tend several species of aphids and mealybugs. Dirt chimneys are often constructed around their charges above ground. Several mealybugs were found stored in a cavity in one tunnel during cold weather. These ants have been seen to attack and eat many kinds of insects.

There are five easily recognizable types of adult individuals in most large colonies of the imported fire ant. They are: alate males and females, dealated females, and major and minor workers. Some authorities have also recognized a media worker form. Very young colonies have minim workers and dealated females. Two color phases have been noted in the Artesia area. The most common color is a dark brown, almost black, with a honey colored band across the mid-dorsal portion of the abdomen of the females and larger workers. A few colonies have been seen in which the ants were a reddish tan color. No colonies with individuals of both colors were seen. This is a point of interest since as many as 25 dealated females have been found in a single colony. A number of colonies in the area of Mobile were examined and a large variation of colors and sizes were seen. The habitat seemed to regulate the colors found in the Mobile area.[1]

There is considerable variation in the speed with which colonies increase in size but about two years are required for a colony to reach maturity or stability in size. Food supply within foraging range is possibly the reason that colonies do not increase in size indefinitely.

The first eggs of the year are laid in the large colonies early in March. These eggs give rise only to alate males and

[1] Courtesy of Leyburn F. Lewis, U.S.D.A., B.E.P.Q. Division of Insects Affecting Man and Animals.

Table 1.—Average distribution of sexual and worker brood pupae in 1949 and 1950.

	PER CENT WORKER PUPAE		PER CENT MALE PUPAE		PER CENT FEMALE PUPAE	
	1949	1950	1949	1950	1949	1950
Late April	29.79	—	60.87	—	9.31	—
Mid May	57.66	44.12	29.16	39.61	13.17	16.24
Early June	94.63	91.19	4.13	6.99	1.95	1.84
Late June	99.62	95.73	0.28	0.92	0.08	3.20
Early August	—	98.17	—	1.13	—	0.67
Mid August	—	98.86	—	0.56	—	0.56
Late August	98.71	99.91	0.62	0.08	0.65	0.00
Early September	—	97.22	—	2.07	—	0.69
Mid September	92.14	98.41	7.64	0.99	0.20	0.58
Late September	99.09	—	0.90	—	0.00	—
Mid October	99.75	98.22	0.11	0.57	0.13	1.20
Late October	78.49	—	20.95	—	0.53	—
Mid November	—	100.00	—	0.00	—	0.00

females. Individuals of the sexual brood range up to about three-eighths inch in length and are often present by hundreds. Several weeks after the sexual brood is started, all colonies begin producing worker brood.

Sample counts of the pupae of males, females, and workers from average sized mature colonies were made during 1949 and 1950. Larvae were not counted since the various types of individuals could not be distinguished. Since no practical method could be devised to determine the variation in total numbers of pupae of the various types of individuals produced in a colony, their numbers were calculated as a percentage from a sample counted from a colony. Table 1 was prepared from averages of usually six samples, containing from about 100 to 2000 pupae. Examinations before the first counts each year revealed all sexual brood, therefore no counts were made.

The percentage of sexual brood produced dropped rapidly in early summer, but did not stop entirely until the approach of winter when all brood production stopped.

Large flights of both sexes of the alate forms were observed on sunny days in the early part of both summers. These flights were attended by great activity of the workers on the plants around the mounds. Following the flights there was a short period during July when no alate forms could be found in the mounds although sexual pupae were present. At all other times during the year, the alate forms of both sexes could be found in the mounds.

Large numbers of small new colonies have been found during the late summer. On poorly drained land these were often about 20 feet apart. An experiment was started in the fall of 1949 to determine the fate of a group of such colonies, but no method could be devised to maintain their identity, due to their many, and apparently aimless, shifts. By mid-winter

Table 2.—Comparison of methods of applying 5 per cent chlordane dust.

	NUMBER OF MOUNDS			SQUARES INCHES OF MOUND AREA		CORRECTED PERCENTAGE OF MOUND AREA REDUCTION AFTER TREATMENT
	Before Treatment	After Treatment	Per Cent Reduction	Beore Treatment	After Treatment	
1. Holes punched, handgun dusted	43	22	48.8	4527	1535	80.7
2. Dust gun with high volume air	42	35	16.7	6842	2109	82.4
3. Spaded and dusted	45	18	60.0	3015	643	87.9
4. Hoed and dusted	46	20	45.5	4461	663	91.5
5. Check no treatment	41	41	0.0	3383	5938	—

Calculated by a modification of Abbott's Formula. Each treatment was calculated as a percentage reduction in mound area, corrected for seasonal increase in mound size as is indicated by the check.

only about 10 per cent of the mounds were surviving, and these were located on higher ground.

INSECTICIDE CONTROL EXPERIMENTS.—A study of the terrain in the infested area around Artesia revealed that control measures would be limited by vegetation, farming practices, and soil type.

Due to tall grasses, mound by mound poison application would be limited to cold weather after frost, when more of the mounds could be seen. Extremely muddy conditions usually prevailing in cold weather would limit these control methods to hand equipment. Also, the very large acreages involved would make applications of high volume water diluted insecticides impractical. The location of many mounds in inaccessible places would make it impractical to combine insecticides with land tillage for eradication purposes.

The only methods considered, therefore, were mound by mound hand treatment with dusts, baits and fumigants, and area treatments of dusts, low volume sprays, and baits.

Preliminary mound by mound treatments with dusts of a number of organic insecticides gave high mortalities; however, it soon became evident that there were considerable numbers of ants escaping and making new mounds nearby. There were often small mounds in the area which were not found during the application of treatments and these added to the difficulty in determining the results. Field toxicity tests gave little quantitative information on the various insecticides tested, but it was evident that dusts of 5 per cent chlordane and 2.5 per cent aldrin and dieldrin were better than 3 per cent gamma isomer BHC, 20 per cent toxaphene or 10 per cent DDT or methoxychlor. Due to its lower order of toxicity to warm-blooded animals, chlordane was preferred over aldrin and dieldrin.

It was found in laboratory toxicity tests that as low as 0.125 per cent dusts of chlordane, aldrin and dieldrin gave complete kills in twenty-four hours. Before an LD_{50} was reached however, these tests were discontinued due to the extremely low concentrations of dusts involved.

While conducting the preliminary tests, several methods of dusting mounds were used with varying success. A test was conducted using 5 per cent chlordane dust applied by four different methods which seemed to have the most merit. These were as follows: Treatment 1 consisted of punching holes in the mound surface at intervals of about 4 inches, and blowing the dust into the holes with a hand plunger duster. Treatment 2 made use of a dust gun which delivered a high volume of dust-laden air under a moderate pressure. The large delivery tube of the gun was pushed to the center of the mound before pumping. After dusting, the gun was used to pump air into the mound to further distribute the dust. Treatment 3 consisted of dusting the ground around the mound, then spading and scattering the mound out on the dusted surface. The hole where the colony was dug up and the spaded dirt and the ants were then dusted again. Treatment 4 was a modification of Treatment 3. Instead of spading the mound out, it was only hoed down level with the ground. In treatments 3 and 4 the dust was applied through a double thickness of burlap sack which was carried in a bucket from one mound to another. Dusting the ground with a gun caused a billowing and loss of dust.

Travis (1938) tested baits on a related species of ants. In his tests all mounds in a given area were given the same treatment to avoid difficulty in determining the number of surviving colonies. A modification of this technique was used in the test described above. Adjacent areas containing about 45 mounds were buffered by stips of the same treatment about fifty feet wide. The average diameter of each mound in each treatment was measured before treating, and the ground area covered by the mounds was calculated considering the mounds as circular. Two weeks after treatment all the mounds in the test including the check were hoed down level and time was allowed for the surviving ants to rebuild. The number and diameter was again recorded to calculate the amount of reduction for the various treatments.

The numbers of surviving mounds show more variance than the percentages of areas surviving; however, the spaded and hoed treatments were superior to those which were dusted with either type of gun.

A number of observations and experiments in 1949 explain the difference in results from various methods of application. It was noted that when a mound was dusted, the ants surviving the treatment moved a few feet away and started a small, new mound. To learn more of how this happened, a small trench about 2 inches deep and a foot from the mound was dug around several mounds. These trenches allowed observations of the activity of the ants in their tunnels. After digging the trench, the ants soon resumed normal traffic. A few alate forms of both sexes were observed in the tunnels at various times and occasionally ants were seen carrying brood in the tunnels. After studying the normal traffic flow, the mounds were dusted with the high volume gun or were fumigated. Within a few minutes after treatment, the ants, including alate forms, would start moving from the mound. Many of the ants carried brood with them. A few hours after treatment, brood could be found cached in many spots near the mound. It was found that they would move under almost any object nearby. Boards placed on the ground were used to trap brood from treated mounds. Samples of this brood were taken to the laboratory and placed in jars for rearing. Most of the brood carried from the treated mounds survived as long as untreated check samples.

Area treatments with dust of 1.25 pounds of chlordane and spray of 1.75 pounds chlordane per acre killed many ants, but only small colonies were eradicated. Large colonies were weakened, but survived the treatment. No land tillage was used in the test.

Various dosages of methylbromide, chlorpicrin, acrilonitrile, carbon disulphide, and cyanide were used at various times of the year with varying temperature and soil moisture. Best results were obtained in hot weather, but all fumigation was inferior to mound dusting with 5 per cent chlordane. Survivng ants put ventilating holes in some mounds fumigated with methylbromide in warm weather and moved back in the mound in a few days.

A number of bait materials were tried with captive colonies and on foraging trails of ants in the field. The most attractive material found was corn meal moistened with vegetable oil. Other materials tested were meats, fish meal, pecan meal, poultry mash, cotton seed hulls, bran, both dry and oiled, and various combinations of sugar syrup, molasses and honey. There was some acceptance of all these materials on the ground surface, but when the bait was introduced directly into a mound, it was sealed in a mass of dirt and ignored.

DDT and dieldrin were incorporated with the corn meal by putting them in solution with the vegetable oil, but even a trace of either poison rendered the bait repellent to the ants.

Ten ml. of saturated thallium sulphate solution was added to 100 grams of corn meal prior to adding 30 grams of oil to form a bait. This material was very effective on captive colonies, but it was ignored when scattered in the field around the mounds.

SUMMARY.—Observations and experiments on the imported fire ant, *Solenopsis saevissima* var. *richteri*, Forel, were conducted in the vicinity of Artesia, Mississippi during 1949 and 1950. The large mounds that this ant builds constitute the most serious objection to its presence. The numerous sexual forms produced and the inaccessible location of many mounds make complete control practically impossible.

Dusting mounds with 5 per cent chlordane, the most effective poison tested, gave good control by several methods of application, but some ants usually survived in the treated areas.

Area treatments with dusts and low volume sprays of chlordane without tillage were effective only against small colonies.

Fumigation of mounds with various chemicals gave generally poorer control than dusting, and baits were not effective in the field.

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Factors Affecting Evaluation of Insecticides against *Anopheles* Larvae

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In the course of attempts to obtain valid statistical comparisons within standard deviations of relatively narrow limits for different larval populations of *Anopheles quadrimaculatus* Say treated with DDT, several factors of interest were encountered. Our early work was carried out using definite numbers of larvae in definite volumes of DDT suspensions. Varying concentrations of DDT were prepared on a parts per million basis. This procedure has been used by a number of other workers, *viz.*, Deonier *et al.* (1945), Kearns *et al.* (1945), Deonier & Jones (1946), and Deonier *et al.* (1946), and is apparently considered to be the standard method for testing mosquito larvae. It is highly satisfactory for either comparative or screening tests as long as the numbers of larvae, the volume of solution or suspension, the surface area, and the type of container are kept constant for comparative tests or between laboratories. Trapido (1951) has recently stressed that these and other factors should be kept constant to obtain valid comparable test results. The average results of such tests, however, are subject to wide variation in the standard deviations. This is illustrated in table 1. These wide deviations can be reduced in some degree by increasing the size of the larval sample since it is readily acknowledged that all things being equal the larger the sample the less will be the variation in results. This is illustrated in figure 1. Here the average expected kill is plotted against the expected range in mortality due to chance sampling in repeated trials for different sizes of sample. From a practical point of view the size of sample should be selected with consideration for the number of larvae available for testing. It would seem desirable to select smaller numbers with several duplicates rather than a single test with very large numbers.

During the course of our work, the decision was made to change the container type from small glass jars to less fragile single service containers to eliminate the tedious cleaning operations necessary to avoid contamination. The pint ice cream cartons used required a greater volume of solution than did the glass jars and gross differences in test results appeared. These differences were partially reconciled when the total amount of DDT present in the two types and sizes of containers was considered. For example, one liter of solution made up to one part per million will contain 1000 micrograms of DDT while 100 cc. of the same solution will contain only 100 micrograms. The numbers of larvae used per container will likewise affect the quantity of DDT theoretically available per larva. To illustrate, when 10 larvae are placed in 100 cc. of a solution containing 100 micrograms, each larva may be considered to be treated with 10 micrograms. When 100 larvae are introduced into the same

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Table 1.—Summary of data obtained on the mortality of 20 early fourth instar *A. quadrimaculatus* larvae in 100 cc. of distilled water containing 0.1 per cent *iso*propyl alcohol and various amounts of *p,p'*-DDT at 64–78° F.

Average Per Cent Mortality[2]	Micrograms DDT per cc.[1]						
	2.0	0.5	0.2	0.05	0.02	0.005	0.002
24-Hour[3]	94.96 ±8.26	80.64 ±20.02	73.70 ±17.23	41.89 ±27.89	28.29 ±22.03	4.95 ±5.29	3.39 ±5.18
48-Hour[4]	100.00 ±0.00	99.07 ±2.21	95.91 ±4.98	67.16 ±25.42	52.11 ±32.09	15.07 ±20.25	10.38 ±16.06

[1] 1 microgram per cc. equals one part per million.
[2] Observed treatment mortality corrected for mortality in the check treatments by means of Abbott's formula.
[3] Means of 22 replicates.
[4] Means of 19 replicates.

Table 2.—Corrected 24-hour mortality of early fourth instar larvae of *A. quadrimaculatus* to 0.1 ppm of DDT per liter in alcohol-distilled water suspension.

Mosquito Strain	Order of Introduction	No. Used	Per Cent Mortality[1]	No. Controls Used	Per Cent Control Mortality
		Test No. 1			
W. D. Insectary	1	200	68	205	0.0
Beaver Dam	2	190	24	191	3.54
Orlando	3	206	16	200	0.50
		Test No. 2			
W. D. Insectary	All	205	67	219	0.9
Beaver Dam	at the	201	62	200	0.0
Orlando	same time	200	83	196	0.5

[1] Corrected by Abbott's formula.

solution the treatment rate would be only one microgram per larva.

Of great importance is the mass-surface area relationship per larva. This can only be determined by experiment. The results of such an experiment are shown on figure 2. It can be observed that with the same applied dosage of DDT, the average kill may vary from 80 per cent to 1.5 per cent just by increasing the number of larvae used in the test. The arrows indicate the expected variation in kill computed on the number of larvae actually used. In most instances the standard deviation of the test was greater than the theoretical

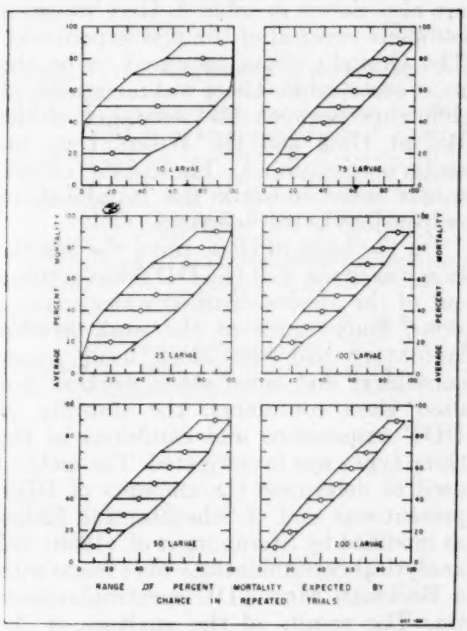

FIG. 1.—Effect of size of larval sample upon range in mortality of replicated tests.

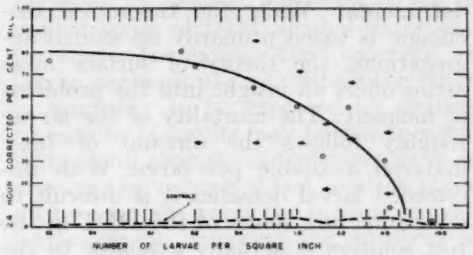

FIG. 2.—Effect of size of larval sample upon the mortality produced by 0.2 micrograms of *p,p'*-DDT per square inch of surface applied as a kerosene film.

value and the variation was greatest with densities greater than one larva per square inch. Crowding apparently has very little effect on the 24-hour control mortality, provided the larvae used are well fed prior to testing. The highest mortality observed in controls was largely due to cannibalism.

The resulting response shown in figure 2 may be attributed to many complex factors. Allee (1926, 1932) discusses cooperative actions among life forms in general. He indicates that organism surface-to-mass ratios may be both beneficial and

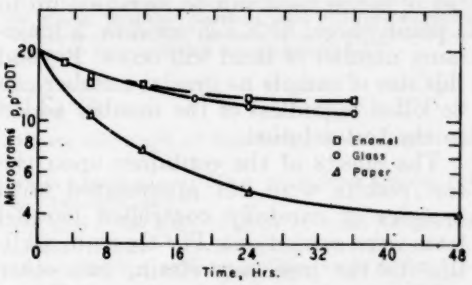

FIG. 3.—Amounts of DDT remaining in suspension in alcohol-distilled water upon standing in three types of containers.

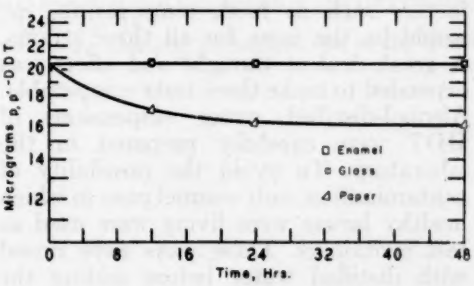

FIG. 4.—Amounts of DDT remaining in suspension in xylene-*Trex* emulsion upon standing in three types of containers.

detrimental. While the theoretical discussion is based primarily on animal aggregations, the theory of surface mass ratios offers an insight into the problems of bioassay. The mortality of the larvae roughly follows the amount of toxic material available per larva. With uncrowded larval densities it is difficult to determine how much of the DDT in the test solution is actually available to the larvae. It is certain that only a fraction of the total amount is used when large areas of the surface are not occupied by the larvae. If one could assume a random distribution of larvae over the entire surface the problem would be simpler. However, it is well known that for the most part *Anopheles* larvae will rest along the edges of the container until crowding occurs. When crowding occurs there is an increased activity which results in greater contact with the DDT but at the same time there is a reduction in the amount of toxic material available per larva. Toxicity tests with large numbers show an increase in the number of larvae killed as compared to tests utilizing smaller numbers, even though the per cent mortality indicates the opposite situation. The number of larvae used can be increased up to a point where, with a given dose, a maximum number of dead will occur. Beyond this size of sample no greater number can be killed regardless of the number added to the test solution.

The effects of the container upon the test results were not appreciated until a series of carefully controlled parallel tests were carried out. For these, in addition to the insectary strain, two other strains, one from the laboratory at Orlando, Florida, and another from the Beaver Dam Creek area of Kentucky Reservoir, were reared to insure that environmental factors such as food, temperature, *etc.* would be the same for all three strains. A great deal of thought and effort was expended to make these tests comparable. Alcohol-distilled water suspensions of DDT were carefully prepared in the laboratory. To avoid the possibility of contamination, only enamel pans in which healthy larvae were living were used as test containers. These pans were rinsed with distilled water before adding the test suspension. Only active, well-fed, early fourth stage larvae were used. In order to eliminate any emotional bias, three persons selected the larvae from the colony, lifting each larva in a wire loop and dropping it into the test solution. The test was conducted under constant temperature of 75° F. and 90 per cent relative humidity. To eliminate any possibility of chance differences, 200 larvae were used in each test. Controls were set up in the same manner. Mortality readings were made at the end of 24 hours.

The results of this experiment are shown in table 2. It came as quite a surprise to observe that the Orlando colony was many times more resistant to DDT than the Wilson Dam insectary strain. Any significance test would rule out the possibility of chance differences. The procedure was again reviewed to find possible failure in obtaining a fair test. It was noted that while all pans were filled with the prescribed amount of test solution at the same time, the larvae were counted in one colony at a time. The selection of larvae began with Wilson Dam and ended with Orlando. It was recalled that some of the Wilson Dam insectary larvae were already dying before the Orlando group was completely set up. The experiment was repeated, except that in the second instance all strains were added to the test solution at as nearly the same time as possible. The results of this experiment are also shown in table 2. Here we see a complete reversal of the first experiment. The Orlando strain appeared to be the most susceptible. There was no significant difference between the resistance of the Beaver Dam and the Wilson Dam insectary mosquitoes. These two experiments serve to show the instability of suspensions as test solutions.

On the basis of these tests, the suggestion was made that the DDT was settling out of the alcohol-distilled water suspensions. Since much of the work in this laboratory had been done using paper containers and since other workers had used glass containers, the stability of DDT suspensions and emulsions in the three types was investigated. The method used to determine the amounts of DDT present was that of Schechter and Haller as modified by Sternburg *et al.* (1950). All analytical determinations were made with a Beckman Model DU spectrophotometer. The results of the analyses of the alcohol-distilled water suspensions and of the xylene-*Trex* emulsions are presented

in figures 3 and 4, respectively. It is readily apparent that there are definite losses of DDT from the suspensions in all three container types, though the rates are much slower in glass and enamel than in paper. Twenty-five per cent of the toxicant had "settled out" nine hours after being set up in both glass and enamel, whereas the same amount was gone after about two hours in paper. At the end of 24 hours 60 per cent remained in suspension in enamel, 57 per cent in glass, and only 24 per cent in paper.

In contrast to the suspensions, emulsions of DDT remain completely dispersed throughout the solution in both glass and enameled containers. At the end of 24 hours in paper containers there is a 21 per cent loss of DDT from the emulsion preparation. This loss, however, does not increase upon standing for at least 48 hours.

Thus to obtain the best test results as far as the amount of DDT remaining in "solution" is concerned, emulsions in either glass or enameled containers appear to be most satisfactory. Paper containers exert adverse effects upon the stability of the toxicant in both the suspension and emulsion preparations.

SUMMARY.—Data have been presented to illustrate the wide standard deviations obtained by testing *Anopheles* larvae in graded series of DDT alcohol-water suspensions. Increasing the numbers of larvae per replicate will reduce the range in mortality to be expected by chance. Variations in results may be due to seemingly small changes in technique such as altering the volume of test solution made up to a certain parts per million concentration or by changing the numbers of larvae utilized per replicate. The mass-surface area relationship per larva has been shown to be of great importance since the mortality from a given dose of DDT may be changed from 80 to 1.5 per cent simply by increasing the number of larvae per test. Finally, the method of dispersion of the toxicant and the type of surface of the test container strongly influence the amounts of DDT remaining in suspension upon standing. Chemical analyses have shown that emulsions are more stable than suspensions and that there is a considerably greater loss of DDT in paper than in glass or enameled containers.

ACKNOWLEDGMENTS—The authors wish to thank all members of the Malaria Control Branch for their assistance in the various phases of the problems discussed. Special thanks are due Dr. T. F. Hall, former Chief of the Biology Section, for his unqualified support and encouragement. The valuable suggestion that DDT might be settling from suspensions was made by Dr. C. W. Kearns. Mr. James Sternburg made numerous suggestions on points of technique necessary to carry out the analytical procedure for quantitative determination of DDT.

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Liquefied Gas-Propelled Sprays for the Home Garden[1]

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The general objectives of this project were discussed in the first report (Owens & Ditman 1950). Following the first year's preliminary work, experimental techniques and designs were enlarged and improved and the number of test vegetable crops increased. Formulations for testing the comparative performance of insecticides were standardized as to amounts and kinds of solvent and propellant used; solvents likely to cause plant injury were eliminated. Because of the large number of insect species encountered, intensive and exact counts could not always be made, but careful yield records, the best criterion of insecticide performance, were made on all crops grown.

METHODS AND MATERIALS.—The apparatus for dispensing the sprays was the same as described in the report referred to above.

The following formulations were tested during the two seasons' work here reported. The last two figures in the formulation refer to the year used.

	per cent
MD-1-50	
Pyrethrum extract (20 per cent pyrethrins)	1.0
Cube resin (33 per cent rotenone)	1.5
DDT	3.0
Methylene chloride	44.5
Methyl chloride	50.0
MD-2-50	
Lindane	1.0
Methylene chloride	49.0
Methyl chloride	50.0
MD-3-50	
Cube resin (33 per cent rotenone)	1.5
Lindane	1.0
Methylene chloride	47.5
Methyl chloride	50.0
MD-4-50	
Cube resin (33 per cent rotenone)	1.5
Lindane	1.0
Acetone	47.5
Methyl chloride	50.0
MD-5-50	
Pyrethrum extract (20 per cent pyrethrins)	1.0
Cube resin (33 per cent rotenone)	1.5
Lindane	1.0
White mineral oil	5.0
Acetone	41.5
Methyl chloride	50.0
MD-6-50	
Pyrethrum extract (20 per cent pyrethrins)	0.5
Cube resin (33 per cent rotenone)	0.5
N-propyl isome	2.0
White mineral oil	5.0
Methylene chloride	42.0
Methyl chloride	50.0
MD-1-51	
Chlordane	2.0
Methylene chloride	48.0
Methyl chloride	50.0
MD-2-51	
Lindane	2.0
Methylene chloride	48.0
Methyl chloride	50.0
MD-3-51	
CS-708[1] (80 per cent solution)	2.5
Methylene chloride	47.5
Methyl chloride	50.0
MD-4-51	
Aldrin	2.0
Methylene chloride	48.0
Methyl chloride	50.0
MD-5-51	
Dieldrin	2.0
Methylene chloride	48.0
Methyl chloride	50.0
MD-6-51	
CS-708	2.5
Lindane	2.0
DDT	3.0
Methylene chloride	42.5
Methyl chloride	50.0

[1] Dilan

Seven kinds of vegetables were planted in individual gardens, 36 by 50 feet, which were arranged in blocks. Each of four blocks contained seven gardens so that each treatment was replicated 4 times. Each garden was composed of a row each of potatoes, tomatoes, cucumbers, cantaloups, snap beans, lima beans, and broccoli. Broccoli, because of its long bearing season, proved unsatisfactory for comparative yield purposes and was replaced with cabbage in 1951. All treatments were applied at weekly intervals from the time plants were set out, or showed above ground, until just before final harvest.

The frequent rains that fell during the 1950 growing season provided conditions favorable to the development and spread of fungous diseases, particularly late blight of potatoes and mildews on cucurbits and lima beans; tomato and cucurbit

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Table 1.—Summary of results of treatments on snap beans.

Formula	Total Yields, Pounds		Average Beans		Mexican Bean Beetle Populations[1]			
					Total No.		Per Cent Control	
	Vines	Beans	Per Lb.	Per Plant	Larvae	Adults	Larvae	Adults
1950								
MD-1-50	65.0	48.1	130.5	31.2	0	137	—	—
MD-2-50	65.4	46.1	136.1	25.8	5	168	—	—
MD-3-50	66.2	49.3	129.9	28.0	3	143	—	—
MD-4-50	62.7	48.3	130.0	26.7	0	126	—	—
MD-5-50	71.8	49.1	136.5	26.9	17	167	—	—
MD-6-50	61.8	43.9	142.1	25.4	50	77	—	43.7
Check	63.8	41.4	141.4	26.7	1	137	—	—
F-value[2]	0.83	0.68	—	—	—	1.26	—	—
1951								
MD-1-51	59.4	64.7	142	21.1	3	51	90.9	13.5
MD-2-51	58.6	71.4	132	24.2	14	66	57.5	—
MD-3-51	68.1	74.5	128	23.1	0	2	100.0	96.6
MD-4-51	53.4	62.4	132	18.9	26	70	22.3	—
MD-5-51	63.9	68.5	126	20.0	0	36	100.0	38.9
MD-6-51	71.7	82.6	111	22.1	0	1	100.0	98.3
Check	54.3	60.5	139	19.3	33	59	—	—
F-value	4.8	4.6	9.2	—	—	—	—	—
L.S.D. at 5%	9.2	10.5	4.7	—	—	—	—	—

[1] Based on counts made between first and second pickings, 2 days after treatments were applied. Estimated by the scoop method, 10 scoops per plot.
[2] For tables 1–9 F-value of 2.66 needed for significance at 5%.

yields were greatly reduced by these causes. The 1951 season was extremely dry and none of the fungous diseases which had been prevalent the year before appeared.

RESULTS.—*Snap beans.*—In 1950 the Topcrop variety of snap beans was planted June 23 and the final picking made August 25, during which time nine applications of all treatments were made. The Supergreen variety was used in 1951; it was planted June 18 and received eight applications of all treatments. Observations during the growing seasons

Table 2.—Summary of results of treatments on lima beans.

Formula	Total Yields Pounds		Average Pods		Bean Beetle Populations			
					Total		Per Cent Control	
	Vines	Pods	Per Lb.	Per Plant	Larvae	Adults	Larvae	Adults
1950								
MD-1-50	—	58.0	44.5	7.3	0	57	—	—
MD-2-50	—	63.1	48.5	8.1	0	54	—	—
MD-3-50	—	63.4	46.5	8.1	0	56	—	—
MD-4-50	—	55.2	46.8	7.5	0	56	—	—
MD-5-50	—	63.9	44.0	7.8	0	67	—	55.1
MD-6-50	—	60.9	46.0	7.5	0	26	—	—
Check	—	46.1	48.0	5.7	0	58	—	—
F-value	—	1.33	2.0	—	—	1.2	—	—
1951								
MD-1-51	63.5	70.2	55.5	8.0	158	4	48.3	84.0
MD-2-51	63.7	83.3	54.4	9.7	36	9	88.2	64.0
MD-3-51	74.2	86.7	55.7	9.5	2	2	99.3	92.0
MD-4-51	63.2	56.1	52.6	5.2	150	21	50.9	16.0
MD-5-51	77.4	61.9	53.0	6.4	159	32	48.0	—
MD-6-51	76.1	90.6	54.0	9.3	40	15	86.9	40.0
Check	64.1	76.0	51.3	8.5	306	25	—	—
F-value	1.06	2.80	0.65					
L.S.D. at 5%		22.8						

revealed no acute foliage injury and no dwarfing or other plant abnormalities that could be attributed to treatments.

Of all the formulations used (Table 1) only those containing CS-708 (MD-3-51 and MD-6-51) were highly effective against adult Mexican bean beetles and only these formulations produced highly significant increases in yields. Plots receiving these two treatments produced larger, better quality fruit (fewer beans per pound) and more per plant than the control plots and plants were larger and more vigorous. Lindane, chlordane, aldrin, and dieldrin showed some effectiveness against the larvae but only lindane produced increased yields. These four materials, however, were not considered adequate.

Lima beans.—The Fordhook type bush lima beans used in these experiments were planted the middle of June and harvested in early September. Eleven applications of each treatment were made in 1950 and nine in 1951. Trends in results (Table 2) were similar to those for snap beans, formulas containing CS-708 giving the highest yields. There appeared to be no significant effect of any treatment on size of fruit, but heaviest yields in plots had the highest number of pods per plant. Lindane and CS-708 formulations were effective against Mexican bean beetle larvae. The rather large number of adults present may have resulted, in part, from the continued heavy influx of adults from a nearby untreated field. Examination of all plots on August 22 revealed slight infestations of black bean aphid on two plots which had been treated with formula MD-3-51; no other infestations were evident.

Broccoli.—Plants were set in the field in early July of 1950 and the crop harvested in August and September. Yields and observations on some of the insect populations present are given in table 3. None of the formulations appeared to be satisfactory though all showed some degree of effectiveness against cabbage looper. The extent of insect populations is indicated by total number of infested plants on September 5 just before application of the ninth and last treatments and again two days later.

Cabbage.—This crop replaced broccoli in the 1951 experiments and proved to be a much more satisfactory crop on which to record yields. Records of injury by loopers and "worms," flea beetles, and aphids and of yields are given in table 4. All formulas were of some value as indicated by increased yields. Those containing lindane, CS-708, or dieldrin and the combinations formulation MD-6-51 were all effective against flea beetle and all species of cabbageworms: the lindane and dieldrin formulations and MD-6-51 showed considerable effectiveness against the cabbage aphid as well.

Cantaloup.—In 1950 the Seneca Bender variety of cantaloup was planted the middle of June, too late to mature fully. With vines heavily injured by downy mildew, all fruit green and ripe was harvested September 18. Because of the severe disease condition no records of insect occurrence were taken; records of yields and set of fruit are given in table 5.

In 1951 the Bender Surprise variety of cantaloup was planted May 25. Because of nutrient deficiency and likelihood of disease all plots were given a weekly spray of magnesium sulphate, borax, and diathans. The aerosol treatments were made as usual in addition to this spray. Eleven applications of insecticides were made in 1950, nine in 1951.

Though results are not statistically significant, lindane performed well as an insecticide on cantaloups, increased yield of fruit and vine weight (Table 5) resulting both years (formulas MD-3-50, MD-4-50, and MD-2-51); aldrin and dieldrin did well in 1951. There appeared to be cumulative injury to vines when CS-708 was used; plants lacked vigor and growth was greatly reduced. Severe infestations of the melon aphid developed on three of the CS-708-treated plots but no infestations developed on any other treated or check plot. None of the insecticides had any direct effect on pollinization in set of fruit.

Cucumbers.—The white spine type of slicing cucumber was used in these experiments both years, being a quick maturing crop it was planted the middle of June. Because severe disease conditions reduced the length of the bearing season in 1950 all plots in 1951 were given, in addition to the aerosol treatments, weekly applications of the same fungicide-nutrient sprays as were given the cantaloups.

Results of the 2 years' work are given in table 6. While results in 1950 were not

Table 3.—Summary of observations on yield and insect infestation on broccoli for the 1950 season.

Treatment	Total Yield, Lbs.	Plants Infested With					
		Before Last Treatment			After Last Treatment		
		Aphids	Loopers	Harlequin Bugs	Aphids	Loopers	Harlequin Bugs
MD-1-50	42.4	20	6	0	6	0	0
MD-2-50	31.6	19	27	0	18	12	0
MD-3-50	36.6	17	14	0	9	3	0
MD-4-50	35.8	20	24	0	4	8	0
MD-5-50	29.2	19	17	0	13	10	0
MD-6-50	36.1	14	23	4	16	9	7
Check	32.7	20	22	9	5	6	8
F-value	0.82	—	—	—	—	—	—

statistically significant, number, set, and yield of fruit and weight of vines for all treatments except MD-6-50 were greater than on the untreated plots. In 1951 significant increases of yield were obtained with dieldrin, lindane, and the combination formula MD-6-51; with these treatments there were also fewer plants lost because of wilt, the only disease present in the field during this season. It is again of interest that the melon aphid developed to severe proportions on the CS-708-treated plots, which accounted in part

Table 4.—Summary of yield records and insect injury to cabbage 1951.

Treatment	Yield, Pounds	Per Cent Plants Injured By		
		Aphids	Loopers and "Worms"	Flea Beetles
MD-1-51	132.1	38.4	100.0	100
MD-2-51	180.9	2.6	5.3	0
MD-3-51	193.0	17.9	5.1	30
MD-4-51	162.4	38.9	22.0	10
MD-5-51	182.5	7.7	3.8	0
MD-6-51	185.6	0.0	2.5	0
Check	74.1	24.3	100.0	100
F-value	12.34	—	—	—
L.S.D. at 5%	35.9	—	—	—

Table 5.—Summary of results of aerosol on cantaloups.

Treatment	Total Pounds of		Number of		Vines Dying of Disease
	Normal Fruit	Vines	Fruits	Fruits per Vine	
1950					
MD-1-50	182.2	163.9	84	.78	—
MD-2-50	170.9	108.7	94	.82	—
MD-3-50	301.1	139.0	123	1.09	—
MD-4-50	218.6	109.2	92	.95	—
MD-5-50	162.4	171.9	88	.77	—
MD-6-50	74.4	106.2	54	.56	—
Control	153.0	90.8	85	.79	—
F-value	1.94	1.11	1.90	1.66	—
1951					
MD-1-51	175.7	108.5	136	1.2	6
MD-2-51	312.5	135.9	160	1.3	1
MD-3-51	102.3	76.6	107	.9	3
MD-4-51	268.6	135.6	156	1.3	0
MD-5-51	265.9	123.1	169	1.4	0
MD-6-51	111.7	93.7	160	1.3	0
Control	246.2	116.2	150	1.3	3
F-value	2.89	4.19	1.62	—	—
L.S.D. at 5%	143.6	31.5			

Table 6.—Summary of results of aerosol treatments on cucumbers.

Treatment	Pounds		Total		Vines[1] Dying of Wilt
	Fruit	Vines	Fruits	Fruits per Vine	
1950					
MD-1-50	632.6	176.8	2591	23.9	0
MD-2-50	539.4	130.8	2293	22.2	0
MD-3-50	617.3	155.9	2548	25.5	0
MD-4-50	657.7	143.3	2628	25.9	0
MD-5-50	633.1	171.0	2488	22.8	1
MD-6-50	429.9	127.8	1994	18.4	0
Check	468.9	118.1	2000	18.9	4
F-value	2.18	1.18	1.44	—	—
1951					
MD-1-51	79.8	14.3	348	3.3	92
MD-2-51	214.4	56.3	812	8.0	34
MD-3-51	110.3	30.3	519	4.7	102
MD-4-51	153.2	36.5	635	6.6	54
MD-5-51	249.7	57.7	846	8.6	35
MD-6-51	207.0	57.3	726	7.6	13
Check	93.5	23.4	375	3.9	77
F-value	7.1	10.3	10.4	—	—
L.S.D. at 5%	73.9	16.3	184.3	—	—

[1] Based on total stand counts after plants became established and counts of healthy plants at last harvest.

Table 7.—Summary of tomato yields.

Treatment	Weight of		Number of Fruits	
	Fruit	Vines	Total	per Plant
1950				
MD-1-50	833.6	230.4	2612	40.8
MD-2-50	704.4	165.3	2162	33.7
MD-3-50	857.0	188.9	2924	45.6
MD-4-50	746.4	190.9	2304	35.9
MD-5-50	797.4	205.9	2546	39.7
MD-6-50	683.1	204.8	2321	36.2
Check	685.1	175.7	2424	37.8
F-value	2.02	1.56	2.51	2.51
1951				
MD-1-51	350.9	—	1001	13.9
MD-2-51	340.7	—	922	12.8
MD-3-51	382.5	—	1083	15.0
MD-4-51	328.9	—	968	13.4
MD-5-51	418.4	—	1126	15.6
MD-6-51	366.5	—	1065	14.7
Check	347.9	—	943	13.0
F-value	0.49	—	0.42	—

Table 8.—Summary of infestations of fruit worm, hornworm, and potato aphid on tomato as recorded September 25, 1951.

Treatment	Total Number of Plants Infested With		
	Fruit-worm	Horn-worm	Aphids
MD-1-51	4	0	all
MD-2-51	1	0	0
MD-3-51	0	0	some
MD-4-51	1	0	some
MD-5-51	0	0	few
MD-6-51	0	0	0
Check	13	12	most

Table 9.—Summary of yield results, flea beetle injury, and leafhopper and corn borer populations on the 1950 potato crop.

	Yield Pounds	Flea Beetle Punctures	Leafhoppers[1]	Corn Borer Entries[2]
MD-1-50	463.9	460	86	22
MD-2-50	182.9	373	152	58
MD-3-50	266.5	400	62	34
MD-4-50	167.4	285	196	29
MD-5-50	303.3	330	91	38
MD-6-50	293.7	742	105	75
Check	171.9	1300	191	46
F-value	6.12	18.59	3.92	1.28
L.S.D. at 5%	126.5	248.2	80.1	

[1] Based on 5 sweeps per plot.
[2] Based on 10 plant samples per plot.

for the low yield with this treatment. There were no aphids on any other plots including the checks.

Tomatoes.—The Rutgers variety was set in the field on June 5 in 1950 and received 13 applications of all treatments. Severe late blight developed and injured many of the fruit; they all, however, were counted and weighed and recorded in the total weight. When vines were pulled and weighed, all green fruit was picked and recorded. The same variety was set in the field June 25 in 1951. No blight developed and only sound ripe fruit was picked and recorded. Eleven applications of all treatments were made in 1951.

Table 10.—Summary of yield results and leafhopper and aphid populations on 1951 potatoes.

Treatment	Yield, Pounds	Degree of	
		Hopperburn	Aphid Infestation
MD-1-51	109.8	medium	on 1 plot
MD-2-51	186.5	slight	on 1 plot
MD-3-51	164.9	none	on all plots
MD-4-51	115.0	slight	on 2 plots
MD-5-51	147.2	slight	on 1 plot
MD-6-51	219.8	none	on 1 plot
Check	126.2	severe	on all plots
F-value	2.26		

Results of treatment on yields and number of fruit are given for both seasons in table 7. Because of the extreme disease conditions in 1950 no observations were made on insect injury, but in 1951 fruitworm, hornworm, and the potato aphid were present; the abundance of these is recorded in table 8.

Yields of tomatoes and set of fruit were not greatly influenced by any of the insecticides used. Best control of the three insect species present was secured in 1951 with formulations containing 2

Table 11.—Summary of the effect of all tested formulations on yield of crop. A single plus indicates a yield greater than the untreated check. A double plus indicates a statistically significant increase, a single minus a yield less than the check while a double minus indicates a significant decrease.

Treatment	Potatoes	Tomatoes	Lima Beans	Snap Beans	Cucumbers	Cantaloups	Broccoli and Cabbage[1]
MD-1-50	++	+	+	+	+	+	+
MD-2-50	+	+	+	+	+	+	−
MD-3-50	+	+	+	+	+	+	+
MD-4-50	−	+	+	−	+	+	+
MD-5-50	+	+	+	+	+	+	−
MD-6-50	+	−	+	−	−	−	+
MD-1-51	−	+	+	++	−	−	++
MD-2-51	+	−	+	+	++	+	++
MD-3-51	+	+	+	++	+	−	++
MD-4-51	−	−	−	−	+	+	++
MD-5-51	+	+	−	++	++	+	++
MD-6-51	+	+	+	++	++	−	++

[1] Broccoli in 1950 and cabbage in 1951.

per cent lindane, though all the formulations greatly reduced fruitworm and hornworm populations.

Potatoes.—In 1950 the Pontiac variety of Irish potato was planted April 6. Eleven applications of treatments were made and potatoes were harvested August 15 to 30, those with dead foliage being harvested first. Records of yields and of flea beetle injury based on 50 leaf samples from each plot, and of leafhopper and corn borer populations are given in table 9. The formula MD-1-50 gave a significant increase in yield; all formulations significantly reduced flea beetle, but only those containing one half per cent rotenone reduced leafhoppers. None of the formulas was effective against European corn borer larvae. There were no Colorado potato beetles or aphids present.

The Sebago variety was grown as a late crop in 1951, planted June 29 and harvested October 25. Eight applications of all treatments were made. Heavy infestations of the potato aphid appeared in September on some plots and leafhoppers were plentiful. Yield results and observations on aphid and on leaf-hopper as indicated by degree of hopperburn are given in table 10. Flea beetle, which was not so plentiful as earlier in the season, caused slight injury only to the check plots and the plots treated with the chlordane formulation and is therefore not recorded.

The formulation containing DDT gave the highest yield, though not statistically significant. The formulation containing CS-708 gave excellent leafhopper control which, however, was not reflected in increased yield where CS-708 was used alone.

DISCUSSION AND SUMMARY.—None of the formulations tested was effective against all the insect species on all the vegetable crops used in these experiments and at the same time was noninjurious to all varieties of vegetable. A summary of the performance of the various formulations is given in table 11. Of all the insecticides used, lindane was generally the most effective and did not cause any retardation of growth. At the concentrations used it did not give desired control of Mexican bean beetle or leafhoppers on potatoes, but it was the best general aphicide. Chlordane and aldrin gave no outstanding performance and seemed to reduce the vigor and yield of some crops. Dieldrin gave excellent results on cucumbers and cantaloups. CS-708 was the most effective Mexican bean beetle and leafhopper insecticide though the rotenone formulations gave excellent results on leafhoppers. For potatoes, formulations containing DDT gave highest yield. Tomatoes generally responded least to insecticidal treatments—they were neither stimulated nor retarded.

Lindane formulations and formula MD-6-50 containing rotenone, pyrethrum, mineral oil, and N-propyl isome caused slight off-flavor in early potatoes. In 1951, flavor of late potatoes was not affected by lindane formulations. No off-flavor of cabbage, cucumbers, cantaloups. tomatoes, lima beans, or broccoli was detected. Slight off-flavor of cooked snap beans which had been treated with lindane was apparent to some tasters.

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Influence of Tree Vigor and Winter Injury on the Lesser Peach Tree Borer[1]

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The relationship between condition of host tree and borer infestation has been considered, as part of a general investigation of peach tree borers (Smith 1951, 1952). The presence of wounds on the bark surface has been recognized as an important factor in the establishment of the lesser peach tree borer, *Synanthedon pictipes* (G. & R.), but specific data on this point have been difficult to obtain. An opportunity to study the relationship

[1] New York Agricultural Experiment Station Journal Paper 888, February 15, 1952.

[2] At the time this study was made, Dr. Harris was Assistant, Department of Pomology, Cornell University, Ithaca, New York. He is now a member of the staff of the University of California at Davis, California.

between tree vigor, winter injury, and borer infestation occurred in connection with a fertilizer experiment which was conducted by staff members of the Pomology Department, New York State College of Agriculture, Ithaca, New York. The results of this study are reported here.

The original experiment was designed to determine the response of Elberta peach trees to various cultural and fertilization practices. Four different treatments were established and maintained for a 3-year period, 1947–1950, and these in time produced distinct gradations in tree vigor. That differences in vigor developed was borne out by the comprehensive data on tree response which were accumulated (Harris & Boynton 1952). The experiment was located in a 12-year old Elberta peach orchard at Morton, New York. Plots consisted of from 4 to 6 trees each and were replicated four times. The plot designations and treatments were as follows:

	Plot Designation			
Fertilization (Lbs. actual nitrogen applied annually)	HC 1.0	HR 1.0	LC 0.5	LR 0.5
Culture	Clean cultivation	Rye grass cover crop	Clean cultivation	Rye grass cover crop

All plots received the same spray program, namely, 4 sprays of DDT and sulfur. The peach tree borer was effectively controlled by this program but it apparently had little effect against the lesser peach tree borer as would be expected from evidence presented in an earlier report (Smith 1951).

METHODS AND RESULTS.—As the experiment progressed the taking of data pertaining to tree response became complicated by the loss of large branches from some trees. This loss was believed to be due to borer activity, and trees severely injured were removed from consideration to avoid the influence of factors believed to be unrelated to the cultural treatments. At first, the number of trees eliminated was evenly distributed, but as the experiment progressed, more trees were eliminated from the high nitrogen plots. At the termination of the experiment, trees which had not been eliminated were carefully inspected and rated on borer injury and gum secretion. The latter was based on the presence of gum unassociated with borer activity. The ratings given by the junior author together with the record of trees eliminated earlier are shown in table 1.

In all cases tree vigor was directly correlated with number of trees eliminated, borer injury and gum secretion. As these ratings were based entirely on visual inspection, it was felt that more specific data could be obtained by an actual count and examination of the borers present. Accordingly, during the spring of 1950 the senior author collected borers from the treatments representing the greatest difference in tree vigor, HC and LR, including the trees which had been eliminated earlier. Unfortunately, the time required prevented the taking of borers from all plots. Those collected were preserved and brought to the laboratory for further study. In comparing the borers taken from trees in the two groups, three criteria were used: one, the number of borers per tree; two, the stage of development of the individuals; and three, the size of mature larvae, as indicated by width of head capsule. The results of these counts are shown in table 2.

A direct correlation was found between the number of borers per tree and the degree of tree vigor, thus susbtantiating the evidence presented in table 1. As regards stage of development, the borers from low nitrogen trees appeared to be slightly more advanced in their development than borers from high nitrogen trees. No significant difference was found in the size of mature larvae. The evidence pertaining to stage of development and size suggests that the vigor of the host tree had relatively little influence on the rate of development of larvae feeding upon it.

DISCUSSION.—The data presented above have shown a direct correlation between borer population and tree vigor, contrary to the belief generally held. While the heaviest infestations shown here are not severe by comparison with some orchards, the differences between treatments are believed to be sufficient to indicate a trend. That such differences should become apparent in the course of three years is striking when it is considered that only three generations of borers developed during this period. Furthermore, it is unlikely that initial treatments produced marked differences in vigor during the first season. This being the

Table 1.—Record of trees eliminated because of borer injury and ratings of trees not eliminated

PLOT	HC	HR	LC	LR
Number of trees at:				
Beginning of experiment	28	26	27	27
End of experiment	17	19	23	24
Number eliminated	11	7	4	3
Per cent of trees eliminated	39.3	26.9	14.8	11.1
Borer injury to experimental trees[1]	4.1	3.7	3.6	3.2
Secretion of gum[1]	3.6	3.2	3.0	2.4

[1] Rating: 1–5
1—No injury
5—Severe injury

case, most of the influence of treatments upon borers must have come in the second and third generation. The practical significance of these findings would possibly have become more apparent had the treatments continued for a longer period.

In attempting to account for the heavier borer population as shown here the question arises: Is this due to greater attractiveness of these trees to the moths for oviposition or is it due to higher rate of establishment of the larvae which hatched upon the trees. It is, of course, possible that both of these factors apply, but for the sake of simplicity they will be considered separately.

HABITS OF THE FEMALE MOTH IN OVIPOSITION.—As larve of this species do not migrate from one tree to another, the number of eggs deposited upon the tree would be expected to have a direct bearing on the number of borers present. The habits of moths in oviposition are, therefore, of interest in this connection. During the oviposition period moths can be observed to hover about the trunk and branches of the trees. After hovering close to the bark for some time, the moth alights and moves slowly over the bark surface swaying the ovipositor from side to side. When suitable areas are located, one or more eggs are deposited in cracks and crevices and flight is immediately resumed. Frequently the moth returns after a short time and again deposits eggs on the same area of the tree. Invariably the moth selects a wounded area for oviposition and the presence of gum seems to attract them. Moths have been observed to visit several trees before locating a suitable site for oviposition. During the past season as part of another study (Smith 1952) over 4000 eggs of this species were collected in the field. In making these collections the presence of eggs in relation to active wounds was readily apparent. The observations cited here indicate marked selectivity by moths in choosing sites for oviposition.

SURVIVAL OF LARVAE.—There must be high mortality among newly hatched larvae under natural conditions. This assumption is based on the fact that field collected eggs show high fertility, approximately 92 per cent; but the number of borers in relation to eggs laid is low. Observations indicate that the critical stage is between hatching and establishment. As shown by Armstrong (1942)

Table 2.—The occurrence of lesser peach tree borers in experimental plots

PLOT	NUMBER TREES EXAMINED	AVERAGE BORERS PER TREE	PER CENT OF BORERS IN EACH STAGE						AV. WIDTH (mm.) OF HEAD CAPSULE OF GROWN LARVAE
			Emerged	Pupae	6th	5th	4th	3rd	
HC-11	5	9.4	2.5	7.5	65.0	22.5	2.5	0	1.97
HC-22	6	14.9	0	4.7	50.0	37.2	8.1	0	2.02
HC-31	5	13.2	0	18.2	52.7	29.1	0	0	2.03
HC-42	5	13.8	3.0	7.6	57.6	28.8	1.5	1.5	2.02
Average		12.8	1.2	9.0	55.0	30.8	3.6	0.4	2.01
LR-12	5	5.8	3.4	10.3	62.2	20.7	3.4	0	2.04
LR-21	4	4.5	0	6.3	62.5	31.2	0	0	2.05
LR-32	5	12.2	5.2	13.8	62.1	15.5	1.7	1.7	2.05
LR-41	6	3.5	0	5.0	55.0	35.0	5.0	0	2.03
Average		6.5	3.3	10.6	61.0	22.0	2.4	0.8	2.04
Difference		6.3[1]							

[1] Significant at 1% level.

larvae are unable to become established on uninjured bark surfaces, and the rate of establishment is extremely low on fresh mechanical injuries. Survival is highest where newly hatched larvae have ready access to active wounds.

CAUSE AND NATURE OF WOUNDS.—It is apparent that both the response of the female in oviposition and the survival of newly hatched larvae are associated with the presence and condition of wounds on the bark surface. In view of this relationship the cause and nature of wounds might be considered. In the experimental orchard wounds were caused largely as the result of winter injury to crotches and large scaffold branches. To a less extent, injuries were due to mechanical causes such as pruning scars and bruises by machinery. Even though only slightly more winter injury could be observed in the high nitrogen trees, a much more conspicuous difference appeared in the condition of the wounds. Profuse gumming was associated with wounds on the high nitrogen trees, while the wounds in most of the other groups appeared relatively free of gum. A greater amount of gumming and borer injury was evident on the trees in plot LR-32 than in the other low nitrogen trees. This particular plot was located in the low part of the orchard where the winter injury may have been more severe due to poorer drainage. The greatest amount of winter injury was to trees in this area of the orchard irrespective of treatment. The trees in plot LR-32 were on the average slightly more vigorous than the trees of the other low nitrogen plots but not significantly so nor did their vigor approach that of the high nitrogen trees. It would, therefore, appear that the amount of gumming was an indication of the severity of winter injury and not an expression of tree vigor in itself.

The relation of these findings to the present borer problem under practical orchard conditions is not definite. Severe infestations, 85 or more borers per tree, are not uncommon in this area. It seems probable in the light of evidence presented here that cultural practices might indirectly predispose trees to heavy infestations if winter injury should thereby be brought about. Associated with this point is the fact that until recently DDT was the chief insecticide used for control of peach pests. While relatively ineffective against the lesser peach tree borer, it likely had some adverse effect upon natural enemies of the pest. This combination of circumstances is believed to account partially for the very heavy infestations encountered in well kept commercial orchards.

SUMMARY.—Data are presented showing a positive correlation between tree vigor and borer infestation. It appears that this situation is due to the more favorable conditions for oviposition and subsequent larval establishment afforded by wounds on trees high in vigor. The wounds in which borers became established were largely caused by winter injury. The establishment of borers was related to the presence and condition of inguries, especially as related to the amount of gum secreted. No evidence was found to indicate that borers initiated injury.

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Control of Peach Tree Borer and Lesser Peach Tree Borer[1]

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Investigations were conducted during 1949 and 1950 to develop a control program effective against the peach tree borer, *Sanninoidea exitiosa* (Say), and the lesser peach tree borer, *Synanthedon pictipes* (G. & R.), (Smith 1951). A program requiring four sprays of parathion applied at the rate of 2 pounds (15 per cent w.p.) per 100 gallons was found to be effective. Sprays were applied at 21-day intervals beginning June 22. In this experiment, the first three sprays accounted for 96 per cent control of the lesser peach tree borer, and the individual sprays gave the following control: June 22, 53 per cent; July 12, 76 per cent; August 3, 61 per cent. The high degree of control resulting from a single treatment was striking considering the prolonged period of moth activity. Laboratory investigations with eggs of the peach tree borer had indicated that the effectiveness of parathion was due in part to ovicidal action. The extent of ovicidal action in the field control of both species was considered in the present study.

Methods.—A suitable orchard having heavy infestations of both species of borers could not be located. Consequently, separate orchards were selected for control studies of each. The lesser borer control program followed during 1950 was essentially repeated, and EPN was also included as a test material. The peach tree borer control program was modified by the omission of the last spray, and additional test materials were included. It was originally planned to evaluate these sprays against both eggs and larvae; however, the time required precluded complete larval counts in case of the lesser peach tree borer. In determining the ovicidal effect of treatments, samples of eggs were collected from sprayed plots after hatching was virtually completed. Peach tree borer eggs could be readily located on the trunk of the tree, and the eggs of the lesser peach tree borer were found along the margin of wounds on trunks and branches. Eggs were removed by cutting away a small piece of bark to which they were attached. A limited number of eggs were taken from each tree to obtain a representative sample of the eggs laid during the course of the season. These samples were brought to the laboratory and carefully examined microscopically with the aid of a binocular microscope. The effect of sprays on the larval population was determined by collecting and examining all larvae present in the fall. Details of this procedure have been described earlier (Smith 1951).

Results on the Lesser Peach Tree Borer.—The timing of sprays in relation to moth emergence is shown in figure 1. The ovicidal effect of these sprays, singly and in combination, is shown in table 1. It is apparent that all sprays had some ovicidal action. Parathion was considerably more effective than EPN. As would be expected, the most effective sprays were those applied before appreciable hatch had occurred. It is interesting to note (Table 1) that a single parathion spray, the curculio spray, applied on June 7 when only 4 per cent of the moths had emerged gave 46 per cent kill of all eggs laid during the season. These results suggest an extended period of ovicidal effectiveness.

Table 1.—The ovicidal effect of sprays on eggs of the lesser peach tree borer.

Treatment	Material	Eggs Examined	Per Cent Hatch	Per Cent Control
Curculio	Parathion	155	50	46
1	Parathion	266	32	65
	EPN	310	60	35
2	Parathion	154	30	67
	EPN	274	67	27
3	Parathion	289	75	18
	EPN	205	86	7
Curculio, 2	Parathion	180	15	84
1, 2, 3	Parathion	209	7	92
	EPN	200	21	77
1, 2	Parathion	240	16	83
	EPN	230	43	53
1, 3	Parathion	203	17	82
	EPN	200	45	51
Check	—	421	92	—

Dates treatments applied: Curculio, June 7; #1, June 21; #2, July 17; #3, August 6.
Parathion (15%) used at the rate of 2 pounds per 100 gallons.
EPN (25%) used at the rate of 20 ounces per 100 gallons.

In interpreting these results, it should be kept in mind that the timing of sprays was based on moth emergence (Fig. 1) rather than on hatching of eggs. Obvious-

[1] New York Agricultural Experiment Station Journal Paper No. 886, February 5, 1952.

ly, the latter is more directly related to the performance of an ovicide, especially when the incubation period is relatively long. In view of this consideration, it seems desirable to present the hatching record which was based on the moth emergence curve. To provide these data the incubation period was determined at constant temperatures. These values were substituted in the equation: $(T-K)D=C$[1] (Uvarov 1931) to determine thermal constant. The validity of this equation when applied to extremes of temperature at which development occurs has been questioned (Davidson 1944). However, as used in this study it is believed to be satisfactory. Mean daily temperature was used to calculate the incubation period at intervals during the season under field conditions. According to these calculations the incubation period for eggs laid early in June was approximately twenty days. This period became progressively shorter until the latter part of July when the shortest period, 10 days, was required. Thereafter, the period increased so that eggs laid in September required approximately twenty-three days. In a limited number of observations, general agreement was found between the actual and calculated period of incubation under field conditions.

The calculated hatching curve together with the probable period of effectiveness of single parathion sprays is shown in figure 2. In estimating this period, it is assumed that a spray was effective in eradicating eggs present at the time of treatment, and, in addition, eggs deposited on the spray residue were controlled for some time thereafter. Such an assumption seems valid in view of the results obtained. Accordingly, the period of effectiveness extends for the duration of the incubation period plus the period of residual effectiveness. The total period of effectiveness of a single spray can then be estimated from the hatching curve when control efficiency of the spray is known. The results as shown in figure 2 are believed to represent reasonably well the actual performance obtained except in case of the third spray which gave less control than would be predicted from the hatching curve.

When the results of multiple sprays are considered, it appears that actual control is slightly less than would be expected from the period of effectiveness ascribed to individual sprays (Fig. 2). This discrepancy might be accounted for in part by the difficulty in obtaining complete coverage under actual conditions.

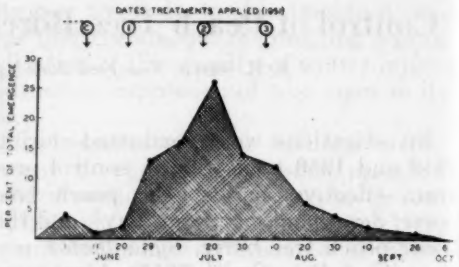

FIG. 1. Timing of sprays in relation to moth emergence.

Counts on the survival of larvae were completed for plots receiving sprays 1, 2, and 3. These results are shown in table 2.

Table 2.—The effect of three sprays of parathion and EPN on eggs and larvae of the lesser peach tree borer.

	Eggs		Larvae		
	Per Cent Hatch	Control	Trees Examined	Larvae per Tree	Per Cent Control
Parathion 2 lbs. (15% w.p.)	7	92	13	6.8	94.2
EPN 1.25 lbs. (25% w.p.)	21	77	7	10.7	91.8
Check	92	—	1	116.0	—

Sprays applied: June 25, July 19, August 6, 1951.

Only one check tree was examined, which is hardly sufficient for calculating per cent control. Although these data are limited,

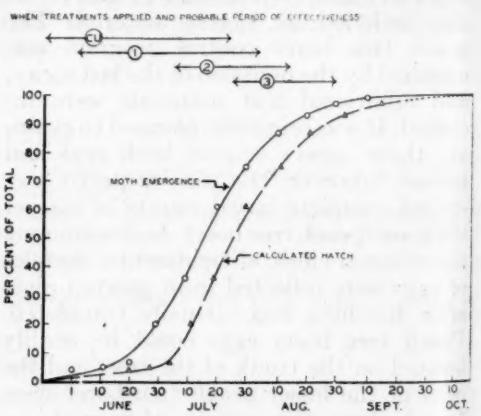

FIG. 2. Moth emergence, calculated hatch, and probable period of effectiveness of treatments.

[1] T = temperature, K = threshold of development, D = number of days, C = thermal constant.

Table 3.—The effect of sprays on the hatching of eggs and survival of larvae of the peach tree borer.

Material and Rate	Date of Treatment 7/17	Date of Treatment 8/10	Eggs Examined	Eggs Per Cent Hatch	Borers[1] Borers per 10 Trees	Borers[1] Control
Parathion (15% w.p.) 2 lbs.	X		131	7%	3	92%
	X	X	126	5	2	95
		X	176	46	8	80
EPN (25% w.p.) 1.25 lbs.	X		162	16	10	75
	X	X	140	26	1	97
		X	111	47	9	77
Malathon (25% w.p.) 1.25 lbs.	X		127	42	12	70
	X	X	117	24	3	92
		X	136	57	21	47
Check			161	98	40	—

[1] These counts include only borers arising from eggs laid during the current season.

the results with parathion are in general agreement with results obtained in 1950, but no previous tests with EPN were available for comparison. The relative effectiveness of EPN and parathion is brought out and differences in manner of performance of the two materials are suggested. In the case of parathion, a high degree of correlation exists between control of eggs and ultimate control based on larval counts. EPN, on the other hand, was not so effective as an ovicide, but the final control was only slightly less than with parathion. This point indicates that EPN also has some effectiveness as a larvicide. The possible larvicidal action of parathion is difficult to determine in the present experiment where 92 per cent control efficiency of eggs was obtained. By using a reduced program—1 or 2 sprays—it might be possible to demonstrate larvicidal action.

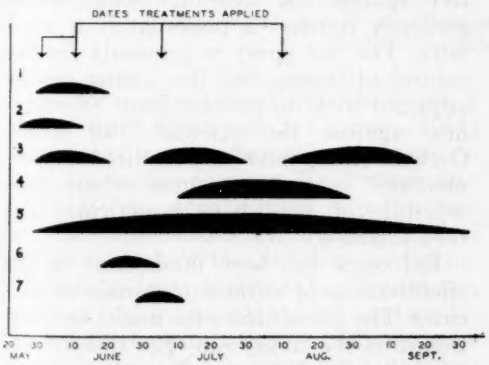

FIG. 3. Timing of sprays in relation to the seasonal development of peach pests. (1) Plum curculio; (2) Plant bug; (3) Oriental fruit moth; (4) Peach tree borer; (5) Lesser Peach Borer; (6) Cottony peach scale; (7) European fruit lecanium.

RESULTS ON THE PEACH TREE BORER.—The effect of sprays on the hatching of eggs and survival of larvae of the peach tree borer is shown in table 3. These results are in general agreement with results obtained against the lesser peach tree borer. It is, however, apparent that single sprays were more effective against this species. All materials tested had some effectiveness as ovicides with parathion being clearly superior in this respect. The results obtained with a single parathion spray (July 19) are striking. Although few eggs had been laid at the time of this treatment, 93 per cent control efficiency of eggs was obtained. Such results would imply that the spray residue remained effective for almost the entire period of oviposition. In all cases, the last spray gave strikingly poorer results, which is probably explained by the hatching which had occurred before treatment was made. It is also of interest to note that the difference in effectiveness of materials was less evident in the last spray. The correlation between kill of eggs and control of larvae was fairly close for the first spray, especially in the case of parathion.

Some inconsistency in counts on ovicidal action of EPN is noted. The last sprays and combination of sprays were in all cases more effective against larvae than against eggs, again indicating larvicidal effectiveness. In this respect, parathion was slightly more effective than EPN. It will be recalled in the previous section that larvicidal action of parathion

was not clearly demonstrated against the lesser peach tree borer. Although parathion was most effective as an ovicide, this difference was not reflected in final control data in plots receiving both sprays. In fact, all three materials gave commercial control when used in two applications. Such programs, providing control from sprays which were applied several weeks before the completion of oviposition, offer obvious practical advantage.

DISCUSSION.—It is apparent from the results cited here that there is no essential difference in the response of the peach tree borer and the lesser peach tree borer to treatments with parathion and EPN. In the case of both species, some of the effectiveness of these materials was due to ovicidal action. The marked ovicidal action of early sprays appeared to be due in part to the effect of spray residues upon eggs deposited some days after spraying. Parathion was considerably more effective than EPN in this respect, but the over-all control as determined by larval survival showed the materials to be about equally effective. Although the two species apparently react in essentially the same way to treatment, there are differences in the life history and habits which seem to account for differences in ovicidal effectiveness. The chief such differences are period of moth emergence and habits of oviposition. The inherent susceptibility of eggs of the two species is assumed to be quite similar, but specific data on this point are lacking. The incubation period was found to be the same for both species. Of the factors believed to be responsible, the period of moth emergence is perhaps most important. The peach tree borer emerges over a period of approximately six weeks, while the lesser peach tree borer emerges during a period of over three months. The differences in habits of oviposition would also be expected to have some practical bearing on control. The peach tree borer females are weak fliers and most of their eggs are laid on the trunks of trees near their point of emergence. The eggs of this species are not deposited in cracks and crevices. The lesser peach tree borer females, on the other hand, are active fliers. Their eggs are deposited in cracks and crevices adjoining wounds on trunks and branches. The period of protection and the thoroughness of coverage required should be greater in case of the latter species. These factors are reflected in results obtained under field conditions. For example, the most effective single spray gave 93 per cent kill of all peach tree borer eggs laid during the season, while the highest kill in case of the lesser peach tree borer was 65 per cent.

Based on the control data cited above, it appears that commercial control of both species can be effected with three sprays. This eliminates the late (about September 1) peach tree borer spray which growers have found most difficult to apply because of its nearness to harvest. Some advantage would be gained in applying the initial lesser peach tree borer spray so that it coincides with the second curculio spray. This change would not alter the general effectiveness of the borer control program (Table 1). The integration of borer sprays with the general control program required for western New York is shown in figure 3. Such a schedule of sprays is at best a rough guide which will require modification to meet seasonal variations. The first two sprays are well coordinated for control of the plum curculio and oriental fruit moth. Additional control measures have not been required for the oriental fruit moth during recent years of relatively low activity. These sprays are too late for maximum effectiveness against plant bugs where these pests present a serious problem. The second spray provides adequate control of early lesser peach tree borers as shown earlier. The third spray is timed to coincide with completion of hatch of cottony peach scale. Sprays applied at this time have also proved effective against the lecanium scale, which generally hatches approximately a week later. The last spray is primarily for the control of borers, but the timing can be adjusted so as to provide some effectiveness against the oriental fruit moth. Orchard mites have not required supplementary control measures where this schedule of phosphate insecticides has been followed.

Reference has been made here to the effectiveness of various materials as ovicides. The use of this term might be questioned as the embryo in eggs affected appears to develop normally to the point of hatching, but the larva fails to emerge through the chorion. Eggs of the plum curculio and oriental fruit moth have been observed by the writer to be affected in a

similar manner by parathion and EPN. In investigations using minimum lethal dosages of petroleum oils against eggs of the oriental fruit moth a similar effect was reported (Smith & Pearce 1948). In eggs having a relatively short incubation period the assumption might be made that the lethal effect of a toxicant such as parathion occurs as the embryo reaches an advanced stage of development. In species having a longer incubation period, such an explanation is questionable considering the short period of residual effectiveness generally ascribed to materials such as parathion. It might be that the persistence of residues on bark surfaces is quite different from that of leaf surfaces on which most of our residue studies are based. In any event, the question arises whether the lethal effect of parathion is brought about just before the time of hatching or whether death of the embryo is the final consequence of earlier exposure to the toxicant. The evidence in these studies is insufficient to warrant conclussion. A marked effect on developing eggs has been demonstrated, and the manner in which this effect occurs is not obvious.

SUMMARY.—Field control studies were conducted during 1951 using parathion and EPN against the lesser peach tree borer and the peach tree borer. In addition, malathon was also tested against the latter species. No essential difference was found in response of the two species to similar treatments. A high proportion of the control obtained could be accounted for through ovicidal action. Parathion was the most effective material tested in this respect. Individual sprays accounted for higher control of the peach tree borer, probably due to the shorter period of moth activity and more exposed location of eggs. Commercial control of both species was obtained using three sprays of parathion or EPN. Changes are suggested in the recommended program so as to eliminate the late spray for peach tree borer control. The integration of these sprays in the general control program is considered.

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Concentration of Several Insecticides for Control of Meadow Spittlebug on Red Clover

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In an earlier paper reporting on 3 years' work, Marshall & Gyrisco (1951) found that benzene hexachloride and dieldrin, the former having a slight superiority at the lower concentrations, were the most effective insecticides tested for the control of the nymph of the meadow spittlebug, *Philaenus leucopthalmus* L. Toxaphene, methoxychlor, chlordane and heptachlor, at relatively heavy concentrations, gave good control of the nymphs, but aldrin and parathion were much less satisfactory because of their poorer immediate toxicity and short residual action. Similar results have been achieved by other workers throughout the country (Weaver 1950; Chamberlin & Medler 1950; Weaver 1951; and others). Data, however, are largely lacking on the minimum effective dosage of many of the synthetic organic insecticides suggested for spittlebug control. Therefore, in the spring of 1950, in conjunction with studies on the control of the clover root borer, *Hylastinus obscurus* Marsham, a series of concentration studies were initiated on the nymph of the meadow spittlebug. The results on the con-

ACKNOWLEDGMENTS.—The authors wish to acknowledge the participation of R. H. Burrage in some of the work reported here.

trol of the clover root borer will be reported in a later paper; this paper is concerned only with results on the control of the spittlebug nymph during the past 2 years.

TESTS IN 1950.—A series of 5 tests using aldrin, dieldrin, heptachlor, lindane and TM-1[1] as dusts were made in a single, large field of first crop year medium red clover. Each insecticide was used at 4 concentrations ranging from 0.35 pound to 1.25 pounds per acre of actual toxicant (Tables 1 to 5). The plots in each experiment were 10 by 20 feet in size, randomized within blocks, and replicated three times. Each experiment was precisely laid out with the aid of a field level which greatly speeded up the work of staking out the experiments. Each concentration of insecticide was weighed out accurately to the nearest hundreth of a gram for each plot of each experiment and then each toxicant was diluted with talc in a mixer and blender to make up 5 pounds in order to facilitate distribution.

On May 23, when the clover root borer was near peak flight and 2 weeks after the first spittle mass had been seen, all the plots in all of the experiments were treated with the aid of a hand fertilizer spreader (Gyrisco & Marshall 1950). The check plots were treated with 5 pounds of talc so that each plot including the checks was handled in an identical manner.

Three weeks after treatment, counts of spittle masses were made in each plot with the aid of a metal frame enclosing an area of 1 square yard. Two samples were taken in each plot from areas chosen at random by throwing the metal frame into the plot. The results from these counts were analyzed by the analysis of variance and are

[1] "Dilan," Commercial Solvents Corporation.

Table 1.—Results of treatments with lindane at various concentrations as a dust against the nymph of the meadow spittlebug on first and second crop year medium red clover. G. Sheldon Farm (1950), Summerville Farms (1951). Fulton, N. Y.

Material	Toxicant Pounds per Acre	Total No. Spittle Masses 6 Sq. Yds.	Avg. No. Masses per Sq. Yd.
1950	First Crop Year	3 Week Count	
Experiment A:			
Lindane	0.35	32	5.3
Lindane	0.50	16	2.6
Lindane	0.75	18	3.0
Lindane	1.25	1	0.1
Check (Talc)	—	101	16.8
Least Significant Difference		(19:1)	8.5
		(99:1)	14.1
Experiment F:	Second Crop Year	2 Week Count	
Lindane	0.35	28	4.6
Lindane	0.50	18	3.0
Lindane	0.65	5	0.8
Lindane	0.75	13	2.1
Check (Untreated)	—	150	25.0
L.S.D. (19:1)			8.7
(99:1)			14.5
1951	First Crop Year	3 Week Count	
Experiment M:			
Lindane	0.50	1	0.2
Lindane	0.75	0	0.0
Lindane	1.00	0	0.0
Lindane	1.25	0	0.0
Check (Untreated)	—	79	13.1
L.S.D. (19:1)			6.7
(99:1)			11.2

Table 2.—A summary of the results from treatments with dieldrin as a dust at various concentrations against the nymph of the meadow spittlebug on first and second crop year medium red clover. G. Sheldon Farm (1950), Summerville Farms (1951). Fulton, N. Y.

Material	Toxicant Pounds per Acre	Total No. Spittle Masses 6Sq. Yds.	Avg. No. Masses per Sq. Yd.
1950	First Crop Year	3 Week Count	
Experiment B:			
Dieldrin	0.35	33	5.5
Dieldrin	0.50	21	3.5
Dieldrin	0.75	7	1.1
Dieldrin	1.25	15	2.5
Check (Talc)	—	101	16.8
L.S.D. (19:1)			8.7
(99:1)			14.5
Experiment G:	Second Crop Year	2 Week Count	
Dieldrin	0.25	42	7.0
Dieldrin	0.35	35	5.8
Dieldrin	0.50	14	2.5
Dieldrin	0.65	9	1.5
Check (Talc)	—	205	34.1
Check (Untreated)	—	215	35.6
L.S.D. (19:1)			11.7
(99:1)			19.5
1951	First Crop Year	2 Week Count	
Experiment N:			
Dieldrin	0.25	0	0.0
Dieldrin	0.50	0	0.0
Dieldrin	0.75	0	0.0
Dieldrin	1.00	0	0.0
Check (Untreated)	—	36	6.0
L.S.D. (19:1)			2.7
(99:1)			3.8

presented in tables 1 to 5, Experiments A to E.

In an adjacent second-cutting year field of medium red clover, a similar series of insecticide concentration plots were laid out. These plots were identical in size and replication to those of the previous tests, except that the concentrations of insecticides ranged from 0.25 to 1.25 pounds per acre of actual toxicant. The concentrations of insecticides were so calculated as to overlap, in some cases, those in the previous experiments.

In this series of experiments, two of the tests were designed with double check plots. One series of check plots in each experiment was treated with talc while the other was left untreated. The purpose of these double checks was to evaluate the toxicity of talc, alone, to the spittlebug nymphs.

On June 2, all of the plots were treated in a manner as previously described. Two weeks later spittle mass counts were made in all of the experiments. Counts were taken 2 weeks after treatment rather than the usual arbitrary 3-week interval because some of the nymphs were beginning to mature and leave the spittle masses at that time. These results are presented in tables 1 to 5, Experiments F to J.

In another adjoining field of first-cutting year medium red clover on the same farm, all of the insecticides, except lindane, which were used as dusts in the other experiments, were used as sprays of emulsions in order to compare the effectiveness of the sprays with the dusts and to find the minimum effective concentration of each formulation. Five insecticides were tried in two experiments at similar concentrations of toxicant per acre. Previous work (Marshall & Gyrisco 1951) had indicated that sprays were several times more toxic than equal amounts of the same insecticide applied as dusts. Therefore the sprays were applied at much

Table 3.—Effect of treatments with heptachlor at various concentrations as a dust against the nymph of the meadow spittlebug on first and second crop year medium red clover. G. Sheldon Farm (1950), Summerville Farms (1951). Fulton, New York.

Material	Toxicant Pounds per Acre	Total No. Spittle Masses 6 Sq. Yds.	Avg. No. Masses per Sq. Yd.
1950	First		
Experiment C:	Crop Year	3 Week Count	
Heptachlor	0.50	109	18.1
Heptachlor	0.75	90	15.0
Heptachlor	1.00	87	14.5
Heptachlor	1.25	45	7.5
Check (Talc)	—	214	35.6
L.S.D. (19:1)			13.9
(99:1)			23.1
	Second		
Experiment H:	Crop Year	2 Week Count	
Heptachlor	0.50	70	11.6
Heptachlor	0.75	84	14.0
Heptachlor	1.00	21	3.5
Heptachlor	1.00	86	14.3
Check (Untreated)	—	192	32.0
L.S.D. (19:1)			9.6
(99:1)			15.9
1951	First		
Experiment O:	Crop Year	3 Week Count	
Heptachlor	0.50	0	0.0
Heptachlor	0.75	0	0.0
Heptachlor	1.00	0	0.0
Heptachlor	1.25	0	0.0
Check (Untreated)	—	38.0	6.3
L.S.D. (19:1)			4.5
(99:1)			6.3

Table 4.—Results of treatments with aldrin at various concentrations as dusts against the nymph of the meadow spittlebug on first and second crop year medium red clover. G. Sheldon Farm (1950, 1951). Fulton, New York.

Material	Toxicant Pounds per Acre	Total No. Spittle Masses 6 Sq. Yds.	Avg. No. Masses per Sq. Yd.
1950	First		
Experiment D:	Crop Year	3 Week Count	
Aldrin	0.35	133	22.1
Aldrin	0.50	120	20.0
Aldrin	0.75	94	15.6
Aldrin	1.25	129	21.5
Check (Talc)	—	171	28.5
L.S.D. (19:1)			17.9
	Second		
Experiment I:	Crop Year	2 Week Count	
Aldrin	0.25	157	26.1
Aldrin	0.35	87	14.5
Aldrin	0.50	75	14.1
Aldrin	0.75	91	15.1
Check (Talc)	—	144	24.0
Check (Untreated)	—	151	25.1
L.S.D. (19:1)			6.5
(99:1)			10.9
1951	First		
Experiment P:	Crop Year	2 Week Count	
Aldrin	0.25	0	0.0
Aldrin	0.50	0	0.0
Aldrin	0.75	0	0.0
Aldrin	1.00	0	0.0
Check (Untreated)	—	70	11.7
L.S.D. (19:1)			1.2
(99:1)			1.5

Table 5.—Effect of treatment at various concentrations of TM-1 as a dust against the nymph of the meadow spittlebug on first and second crop year medium red clover. G. Sheldon Farm, Fulton, New York. 1950.

Material	Toxicant Pounds per Acre	Total No. Spittle Masses 6 Sq. Yds.	Avg. No. Masses per Sq. Yd.
	First		
Experiment E:	Crop Year		
TM-1	0.50	122	20.3
TM-1	0.75	185	30.8
TM-1	1.00	132	22.0
TM-1	1.25	115	19.1
Check (Talc)	—	200	33.3
L.S.D. (19:1)			16.6
(99:1)			27.5
	Second		
Experiment J:	Crop Year		
TM-1	0.50	72	12.0
TM-1	0.75	56	9.3
TM-1	1.00	60	10.0
TM-1	1.25	31	5.1
Check (Untreated)	—	118	19.6
L.S.D. (19:1)			6.7
(99:1)			11.1

Table 6.—Effect of treatment with benzene hexachloride, heptachlor, dieldrin, aldrin and TM-1 as sprays in 2 experiments at several concentrations against the nymph of the meadow spittlebug on first cutting year medium red clover, G. Sheldon Farm Fulton, New York. 1950.

		Experiment K		Experiment L	
Material	Toxicant Pounds per Acre	Avg. No. Masses per Sq. Yd.	Per Cent Reduction	Avg. No. Masses per Sq. Yd.	Per Cent Reduction
BHC	0.05r	1.0	97.2	5.6	91.1
	0.10r	0.6	98.4	1.3	97.9
	0.15r	0.0	100.0	0.6	99.0
Dieldrin	0.05	7.0	80.5	25.6	59.5
	0.10	2.3	93.6	13.0	79.9
	0.15	1.6	95.6	10.3	83.7
Aldrin	0.05	10.0	72.2	44.0	30.4
	0.10	8.6	76.1	30.3	52.1
	0.15	6.3	82.5	10.3	93.7
Heptachlor	0.05	11.3	68.6	36.0	43.1
	0.10	5.0	86.1	38.0	39.9
	0.15	5.6	84.4	19.0	69.9
TM-1	0.05	—	—	52.9	16.9
	0.10	—	—	43.6	31.1
	0.15	—	—	20.3	67.9
Check (Untreated)		36.0	—	63.3	—

lower dosages than the dust. The plots were 20 by 80 feet in size and were not replicated.

All of the sprays were prepared from proprietary formulations of emulsifiable concentrates. The insecticides were weighed out for each concentration and placed in stoppered bottles for carrying into the field. After each concentration was used, the tank, hoses and boom were flushed out with 2 to 4 gallons of clean water before the next treatment was applied.

All the insecticides of Experiments K and L were applied on May 17 and May 24, respectively with the aid of a trailer-type, low pressure, low volume sprayer. The sprayer was equipped with an 18-foot boom which had 15 flat fan-type nozzles equally spaced throughout its length. At a pressure of 40 pounds per square inch, the sprayer delivered 1 gallon of spray per minute. With a tractor speed of 0.9 mile per hour, one gallon of emulsion spray covered 1600 square feet a minute.

Spittle mass counts were made in a manner described previously except that the results could not be analyzed by the analysis of variance because of the design of the experiment. Therefore the results are presented in table 6 merely as a per cent reduction in the population. It is not known whether the differences in control are significant where the differences are not great.

Tests in 1951.—During 1951, a series of dust experiments similar to those of 1950 were applied in 4 experiments on May 15, 16 and 17 on 2 different fields of first-cutting year medium red clover. Aldrin, dieldrin, heptachlor and lindane were all used at the same rates per acre of actual toxicant as the previous year. The plots, however, were a little larger in size, measuring one two-hundreth of an acre, and were replicated 4 times. The dusts were handled and applied in a manner as previously described.

Counts of spittle masses were made 3 weeks after the treatment of each experiment and these results were again analyzed by the analysis of variance. These results are presented in tables 1 to 4, Experiments M to P. The counts for 1951, however, were adjusted to fit the tables so that the total number of spittle masses for 6 square yards rather than 8 square yards (taken in 1951) is given.

Discussion of the Results.—A quick comparison of the results for 1951 with those of the previous year indicates that even a material such as aldrin, which did not prove satisfactory in previous work, appears to give good spittlebug nymph control even with the lowest con-

centration of toxicant. However, a closer examination of the 1951 results shows that the infestation was very low during that year. Lack of masses therefore in the treated plots does not necessarily indicate control in those plots, but rather a lack of infestation. Since the untreated plots had small populations of spittlebug nymphs, small changes in populations of the treated plots would be reflected as great changes in control if such populations are compared on a per cent basis. Therefore, the actual counts and differences should be compared. It is believed that the data for 1951 should be considered lightly in view of the data from the previous 4 years' work (Marshall & Gyrisco 1951).

Discounting 1951, during which year the populations of spittlebugs were very low, there appeared to be no difference in the infestations of spittlebugs on the first-cutting year red clover and the second-cutting year clover. The spittlebugs were neither more resistant nor more susceptible to insecticides on either of the two ages of red clover.

Lindane and dieldrin were the best materials tested as dusts and gave fair to good control at all concentrations at which they were used. Heptachlor gave fair control at 1.25 pounds per acre but was not wholly satisfactory. Aldrin, metacide and TM-1 as dusts were not satisfactory at any of the concentrations at which they were tested.

While lindane, as a dust, gave fair control at 0.35 pound per acre, it appears that at least 0.5 pound per acre of lindane should be used as a dust to give satisfactory control. Dieldrin was similar to lindane in its toxicity and a similar concentration should be suggested for spittlebug nymph control. Heptachlor was inferior to lindane and dieldrin and at least 1.0 pound per acre as a dust is needed to give fair spittlebug control. A heavier dosage is suggested. Aldrin and TM-1, even at dosages of 1.25 pounds per acre, did not give satisfactory control. Talc alone showed no toxicity to the spittlebug.

As a spray, only benzene hexachloride gave good control at all the concentrations at which it was used (Table 6). Dieldrin, while giving good control in one experiment, fell down in the second experiment but still gave fair to good control at dosages of 0.10 and 0.15 pound per acre. Aldrin, heptachlor and TM-1 gave poor to fair results at all of the concentrations at which they were tested. Heavier concentrations of these insecticides as emulsions are suggested if they are to be used for spittlebug control.

Emulsion sprays again were superior to heavier concentrations of the same insecticides as dusts.

SUMMARY.—In a series of concentration studies on medium red clover during 1950 and 1951, lindane was found to be effective for spittlebug control at dosages as low as 0.5 pound per acre of toxicant as a dust and as an emulsion (benzene hexachloride) at concentrations as low as 0.05 pound per acre of gamma isomer. Dieldrin was similar to lindane in its toxicity as a dust but was slightly inferior to lindane as a spray. Heptachlor at 1.0 pound per acre as a dust gave fair control but aldrin, TM-1 and metacide were all unsatisfactory at all the concentrations at which they were tried.

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Rotary Brush Units for Aerial Spraying Against Mosquitoes and Black Flies[1]

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During recent years a concerted attempt has been made to control *Aëdes* mosquitoes by aerial sprays applied over large areas surrounding communities in subarctic Canada. For this purpose an aircraft[3] has been employed, fitted with a gravity-feed straight emission pipe. The larvicidal application of DDT at 0.25 lb. per acre killed approximately 90 per cent of the larvae, but reduced the subsequent adult population during the summer by only 50 per cent (Twinn, *et al.* 1950). Application against adults at approximately 0.5 lb. per acre achieved almost 100 per cent control, but at about 0.25 lb. per acre the reduction was unsatisfactory (Goldsmith *et al.* 1949). When this method was employed on extensive operations against adults at an average dosage of 0.23 lb. per acre, between 64 and 99 per cent control of adult mosquitoes was obtained at the various stations treated (Sharp, prepared for publication). When an air-scoop was fitted to the straight emission pipe, application of 0.17 lb. per acre over an area of 19 sq. mi. achieved 86 to 98 per cent control of adult mosquitoes, sufficient to give adequate reduction in the population for four weeks (Brown *et al.* 1951).

Although the straight emission pipe, with or without air-scoop, is satisfactory for operations against larvae, it gives too coarse a droplet spectrum to be economical for treatment against the adults. The spectra obtained with DDT in polymethylnaphthalenes (Velsicol) and fuel oil showed mass median diameters between 300 and 400 microns, and some droplets larger than 500 microns in diameter, which are wasteful as far as killing adult mosquitoes is concerned. Therefore, attention was paid to using an apparatus that could be fitted on to the straight emission pipe and that gives sufficiently thorough atomization to avoid the production of coarse droplets. Such an apparatus is afforded by a sheaf of rotary brushes driven by an outboard propeller, models of which are obtainable commercially.

Apparatus.—*Rotary brush.*[4]—Consisting of a sheaf of aluminum discs fringed with a brush of fine wire and sandwiched between a 10-in. disc of sheet aluminum ("cone widener") and a hub cap that could be screwed on tightly (Fig. 1). This sheaf is rotated on a horizontal shaft by a wooden propeller 23 in. in diameter and with a pitch of 50°, steep enough to be adjusted to the high speed of the aircraft. The rotary brush was mounted under the fuselage of an aircraft[5] in place of the vertical emission pipe, with a short lead of pipe so that the distance from the rotor shaft to the fuselage skin was 16 in. and the shortest distance from the propeller tip to the ground, when the aircraft was stationary, was 17 in. (Fig. 2).

Five brush discs were assembled in such a way (arrangement "C" of the manufacturer) that three brushes 10 in. in diameter with 0.0118 wire were alternated with two brushes 8 in. in diameter with 0.005 wire. When the aircraft flies at 150 m.p.h. the unit is expected to turn at 2500 r.p.m. Under these conditions, the average emission rate of the 10 per cent DDT solution was determined to be 1.05 gal. per second over the full tank load; visual examination indicated that this rate, with the gravity feed employed, did not vary greatly with the hydrostatic head in the tank, and that it was considerably more regular than with the straight emission pipe. When DDT concentrate (20 per cent) was emitted, only three brushes were used and they were all 8 in. in diameter with 0.005 wire; the average emission rate was 0.58 gal. per second.

Methods.—The spruce forest at Goose Bay, Labrador, was selected as the locale for these tests, and a total of 30 sq. mi. was sprayed at different dosages, spray concentrations, and brush assemblies. The area sprayed was divided into

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[3] Dakota DC3 (C-47).

[4] Model 851, was purchased from Independent Crop Dusting Inc., Campbell, California.

[5] Dakota.

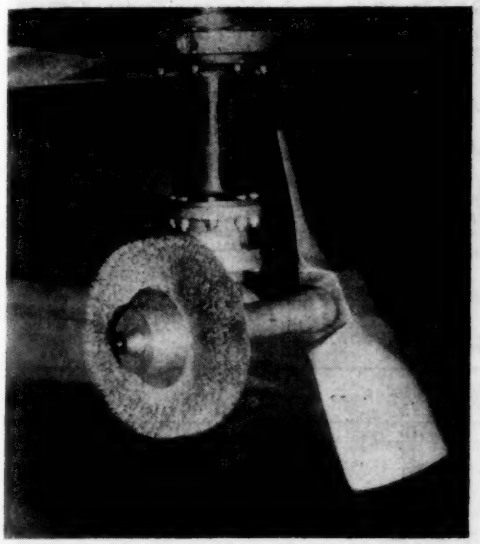

FIG. 1.—Rear view of rotary brush unit with five-brush assembly installed under fuselage of Dakota C-47.

three blocks, each consisting of several plots (Table 1), and each block received a different treatment. The first block was treated with 10 per cent DDT solution dispersed by the five-brush assembly. In the second block, the dosage was halved by substituting 5 per cent DDT as the spray solution. In the third block, the expenditure of solvent was halved by using 20 per cent DDT dispersed by the slow-emission three-brush assembly.

Applications were made in the evenings (with one exception) between June 30 and July 17, 1951. All emission runs were made at 150 m.p.h. ground speed. Although the author was aware of the relation of the height-wind product (Brown 1951) to the cross-track spread of droplets, it was decided to perform all flights at 100 ft. above terrain regardless of the speed of the cross-wind component, and to lengthen the interval between successive lines of flight to 300 yd.

A 25 per cent concentrate of DDT in trimethylnaphthalene[1] was diluted in No. 2 fuel oil (also called diesel oil). Two hundred and fifty gallons were loaded into each of two tanks, making a 500-gal. air load. The first arrangement, with five brushes, allowed a total emission time of 477 sec., sufficient to cover 3.4 sq. mi.; the second arrangement, with three small brushes, allowed 860-sec. emission and a coverage of 6.1 sq. mi.

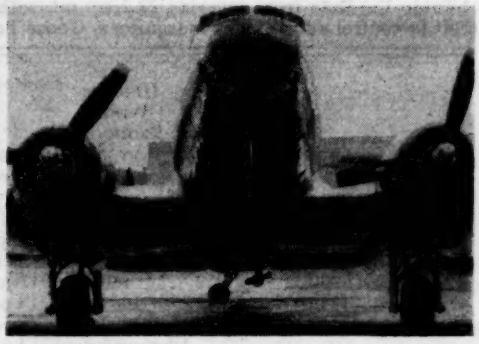

FIG. 2.—Front view of Dakota C-47 aircraft showing the position of the rotary brush unit slightly port of center and slightly forward of the side loading doors.

Control was measured by taking landing rates of mosquitoes the day before and the day after spraying. The observer waited at a spot for 1 min.; then, watching the front of the trousers between knees and belt, he counted the black flies landing on them during the second minute, and the mosquitoes landing during the third minute. As far as conditions allowed, sampling points were taken every 100 yd. on a line running at right angles to the emission runs.

The spray was assessed for droplet size and dosage by a line of sampling points running for 900 yd. downwind and cross-track of the aircraft, which was flown at a height of 100 ft. at right angles to the wind direction. The droplets were caught on coated microscope slides[2] and sized microscopically, a spread factor of 0.5 being assumed. The dosage was determined by catching the spray dyed red, on 4-in. petri dishes and assessing the deposit density colorimetrically. The airborne component of the spray was sampled by cascade impactors operated at 17.5 liters per minute.

RESULTS.—Details of the acreage treated, the dosage of DDT, and the degree of control as indicated by pre-spray and post-spray assessments at the same points are shown in table 1.

With 10 per cent DDT, 10.2 sq. mi. was sprayed at 1.05 gal. per sec., giving an average dosage of 0.22 lb. of DDT per acre; this was done in three flights, two of which each covered two areas differing in forest cover type. The reduction in landing rate of mosquitoes varied from

[1] Velsicol AR-60.
[2] Coated with G.E. Drifilm 9987.

Table 1.—Data from spraying 28.2 sq. mi. with DDT by rotary brush units on a Dakota C47 aircraft to control adult *Aëdes* mosquitoes, Goose Bay, Labrador.

Plot No.	Area Acres	Dosage lb. per Acre	Height Wind Product ft.-mi./hr.	Forest Type	No. of Samples	Total Count			Reduction Per Cent
						Pre-spray	Post-spray Incl. Edges	Post-spray Excl. Edges	
				10% DDT, 1.05 gal./sec.					
I	2048	0.232	1200	Dense	33	1244	57	10	99.2
II	1310	0.230	400	Open	18	96	0	0	100.0
III	960	0.212	450	Dense	15	350	24	5	98.6
IV	1040	0.217	1000	Dense	16	189	7	5	97.4
V	1150	0.217	1000	Open	24	43	1	1	97.7
			Average(weighted by area)						98.7
				5% DDT, 1.05 gal./sec.					
VI	2250	0.111	700	Dense	25	430	164	93	78.3
VII	1060	0.112	1200	Open	15	79	1	1	98.7
VIII	1000	0.112	1200	Dense	12	198	30	30	85.1
XI	2240	0.117	300	Dense	21	285	47	22	92.5
			Average						87.4
				20% DDT, 0.58 gal./sec.					
X	1600	0.261	400	Dense	23	71	10	7	90.2
XI	2200	0.262	200	Open	36	10	0	0	100.0
XII	1230	0.275	200	Dense	14	203	104	13	94.3
			Average						96.5

97.4 per cent to 100 per cent, and averaged at 98.7 per cent.

With 5 per cent DDT, 10.2 sq. mi. was sprayed at 1.05 gal. per sec., giving an average dosage of 0.11 lb. per acre. The control of mosquitoes averaged 87.4 per cent, ranging from 98.7 per cent in the open forest to 78.3 per cent in a plot that contained spots of very dense forest, in which the landing rate was reduced by only one-fifth; this plot was treated in the morning, when the air temperature was only 48° F.

With 20 per cent DDT, 7.8 sq. mi. was sprayed at 0.58 gal. per sec., giving an average dosage of 0.267 lb. per acre. The average population reduction of mosquitoes was 96.5 per cent.

It was more difficult to evaluate the effect of the spray treatments on black flies (Simuliidae), since they are highly mobile and their numbers and activity vary widely. However, the pre-spray and post-spray assessments for the three different treatments gave the figures shown below.

Treatment, DDT Lb. per Acre	Pre-Spray	Post-Spray	Reduction
10% DDT, 0.22	84	17	80%
4% DDT, 0.11	42	32	24%
20% DDT, 0.27	414	55	87%

Table 1 shows that the maintenance of the flying height at 100 ft. above terrain resulted in a variety of height-wind (HU) products because of the various wind speeds and directions prevailing at the time of each treatment. The fineness of the spray dispersed from the rotary brushes was sufficient to ensure coverage of the 300-yd. swaths in all cases of height-wind products varying down to 200 ft.-mi. per hr. over open woodland, and down to 300 ft.-mi. per hr. in dense woodland. In plot 12 which was dense woodland treated at a HU product of only 200 ft.-mi. per hr., the lack of coverage was evident in the non-reduction of mosquito population from 200 to 300 yd. cross-track of each emission run. The population reduction reported in table 1 for plot 12 is based on counts at sampling points 100 yd. and 200 yd. cross-track of each emission run, the 300-yd. sampling points being omitted from consideration.

An additional 1.8 sq. mi. was treated during special flights made to assess the droplet size and the deposits obtained with each of the two brush assemblies. The figures for these assessments are shown in tables 2 and 3. For each brush assembly a determination was made of the droplet spectrum of the spray deposited at successive distances downwind and cross-track, of the droplets remaining

Table 2.—Assessment of spray from five-brush assembly of a rotary brush unit (10% DDT emitted at 1.05 gal./sec. Height-wind product 1050 ft.-mi./hr.).

	Droplet Spectrum												
Diameter in microns	*18*	*27*	*36*	*45*	*54*	*72*	*90*	*112*	*135*	*180*	*225*	*270*	*315*
Per cent of total number of droplets	3.7	13	18	23	31	41	52	67	78	92	97	99	100
Per cent of total mass of droplets	.01	.07	.17	.33	0.8	2.2	5.1	11	23	55	74	95	100
Median diameter = 97 microns.					Mass median diameter = 195 microns.								
	Material Deposited on Ground												
Distance downwind (cross-track) yards	*200*	*225*	*250*	*275*	*300*	*325*	*350*	*375*	*400*	*500*	*600*	*700*	*800*
Deposit densities lb. per acre of DDT	0.27	0.32	0.62	0.28	0.21	0.38	0.28	0.25	0.09	Tr.	Tr.	Tr.	Tr.
Mean (arithmetic) diameters of droplets in microns	315	270	142	193	163	168	96	97	72	78	48	39	30
	Material Remaining Airborne												
Diameter in microns	*9*	*18*	*27*	*36*	*45*	*54*	*72*	*90*					
No. of droplets recovered at 450 yd.	32	26	13	4	5	3	5	2					
No. of droplets recovered at 900 yd.	40	17	6	4	1	—	—	—					
Mass median diameter at 450 yd. = 65 microns; at 900 yd. = 27 microns.													

airborne at 450 and 900 yd. cross-track, and of the deposit densities for a distance of 500 yd. cross-track.

The spread factor for lenses formed by the spray droplets on the film surface was determined by the method of May (1945); the 10 per cent DDT solution in trimethyl naphthalene and fuel oil had a refractive index of 1.53. For droplets between 100 and 200 microns in diameter this factor averaged 0.5, and for 50-micron droplets it decreased to 0.45. This spread factor was not found to decrease, due to an increase in lens diameter, during the three hours required for the assessment; however, certain lenses did lose their circular outline and introduced the factor of judgment in the measurement of their diameter. The figures tabulated in tables 2 and 3 are based upon a spread factor of 0.5, *i.e.*, the diameter of the droplet is taken as half the diameter of the lens it produces on the film surface.

Table 2 shows that the five-brush assembly emitting 10 per cent DDT solution at 1.05 gal. per sec. gave a droplet spectrum the mass median diameter of which was 195 microns. There were no droplets larger than 315 microns in diameter, and about 50 per cent of the volume of the spray was included in the sizes between 135 and 225 microns. Approximately 8 per cent of the volume occurred as droplets smaller than 100 microns in diameter. When dispersed at a height-wind product of 1050 ft.-mi. per hr., the largest droplets did not reach the ground until they were 200 yd. downwind of the aircraft, and the heaviest deposit fell at a distance of 250 yd. downwind and cross-track. The cascade impactor samples showed that droplets up to 90 microns in diameter were still airborne at 450 yd. downwind, and up to 45 microns at 900 yd. downwind.

Table 3 shows that the three-brush assembly emitting 10 per cent DDT solution at 0.58 gal. per sec. gave a droplet spectrum the mass median diameter of which was 180 microns. The largest droplets were again in the 315-micron class, while as much as 60 per cent of the volume of the spray consisted of droplets ranging from 135 to 225 microns. Approximately 15 per cent of the volume occurred as droplets smaller than 100 microns. When dispersed at a height-wind product of 400 ft.-mi. per hr., the largest droplets reached the ground 50 yd. downwind of the aircraft, and the maximum deposit was 100 yd. cross-track. Cascade impactor samples showed that droplets up to 35 microns in diameter remained airborne at distances of 450 and 900 yd. downwind.

DISCUSSION.—Table 1 shows that the best results against mosquitoes were obtained with 10 per cent DDT solution ap-

Table 3.—Assessment of spray from three-brush assembly of a rotary brush unit (10% DDT emitted at 0.58 gal./sec. Height-wind product 400 ft.-mi./hr.).

	Droplet Spectrum												
Diameter in microns	*9*	*18*	*27*	*36*	*54*	*72*	*90*	*112*	*135*	*180*	*225*	*270*	*315*
Per cent of total number of droplets	6.9	16	26	39	48	56	70	80	86	97	99	99	100
Per cent of total mass of droplets	.01	.04	0.2	0.6	1.5	3.3	9.7	20	29	67	89	98	100
Median diameter = 65 microns. Mass median diameter = 180 microns.													
	Material Deposited on Ground												
Distance downwind (cross-track) yards	*50*	*75*	*100*	*125*	*150*	*175*	*200*	*300*	*400*	*500*	*600*	*700*	*800*
Deposit densities lb. per acre of DDT	0.76	3.30	1.86	0.80	0.12	0.16	0.03	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Mean (arithmetic) diameters of droplets in microns	219	189	114	86	54	41	41	29	27	23	17	20	19
	Material Remaining Airborne												
Diameter in microns	*9*	*18*	*27*	*36*									
No. of droplets recovered at 450 yd.	56	40	31	4									
No. of droplets recovered at 900 yd.	13	12	3	1									
Mass median diameter at 450 yd. = 17 microns; at 900 yd. = 13 microns.													

plied at a dosage of 0.22 lb. (gal.) per acre. Reduction of the dosage to 0.11 lb. per acre, by reducing the concentration of the spray to 5 per cent DDT, resulted in inadequate control. Reduction of the total volume of spray but not of the dosage, by increasing the concentration to 20 per cent DDT, did not give quite so good results. Against black flies the 20 per cent DDT solution was applied at the peak of infestation and the 87 per cent population reduction is probably a true representation. However, the experiments with 5 and 10 per cent DDT solutions were conducted during a period of rapidly rising numbers of black flies, and the 80 per cent reduction with 10 per cent DDT at 0.22 lb. per acre probably represents practical elimination of black flies in the area at the time of spraying. It may be stated that the application of 10 per cent DDT at 1 gal. per sec. from the Dakota aircraft at 300-yd. intervals, the first method to be selected in these trials with the rotary brush, gives the most satisfactory and economical results against adult mosquitoes and black flies in the Canadian subarctic.

In addition to achieving better control of adults than the straight emission pipe for which it was substituted, the rotary brush allows great economy in flying time. For expenditures of 0.25 lb. of DDT per acre, the straight emission pipe method dispersed 4 per cent concentrations in 200-yd. swaths and allowed only 1 sq. mi. to be covered per flight; the rotary brush dispersed 10 per cent solutions in 300-yd. swaths and covered as much as 3.4 sq. mi. per flight. When 20 per cent DDT is used with the three-brush assembly, 6.1 sq. mi. may be covered per flight without much loss in efficiency, the control still being better than that with the straight emission pipe.

Also, the use of 10 per cent (wt/vol.) solution with the rotary brush allows a considerable saving in diluent as compared with the 4 per cent (wt/wt) solution previously employed. The amount saved is 365 gal. per square mile, only 90 gal. of fuel oil being required to dilute every 45 gal. of 30 per cent DDT concentrate instead of the 455 gal. formerly required for the 33 per cent concentrate used (see Twinn *et al.* 1950). This saving becomes even more marked if 20 per cent solutions are employed.

A further point of practical importance is that this method allows satisfactory coverage at a wide range of height-wind products. Thus the air-crew may be instructed to maintain a fixed flying height of 100 ft. above terrain. This is sufficient to allow overlap even with lines of flight 300-yd. apart provided that the height-wind product is not less than 400 ft.-mi. per hr., *i.e.*, such as is provided by a 4-m.p.h. cross wind. In light winds it is recommended that the spraying height

be raised to 150 ft. and in very light winds to 20 ft. above terrain.

There is no doubt that there is room for improvement in the fitting of the rotary brush for applications to control adult mosquitoes from Dakota aircraft. The present position of the unit is too close to the fuselage, and much of the spray is caught up into the slip stream in the tail region. It could not be put lower owing to the danger of its propeller catching on the runway upon landing. It is possible that it could be placed farther forward and thus lowered a greater distance from the fuselage skin. Also, droplet size investigations may indicate that even finer sprays are more effective. However, it is the opinion of the author that substantially finer atomization would be difficult to achieve with brushes emitting so great a volume of spray, and that difficulties of target-finding at practical flying heights above woodland would result.[1]

SUMMARY.—A rotary brush unit was tested on a Dakota DC3 (C-47) aircraft for its suitability for control of adult *Aëdes* mosquitoes in subarctic spruce forest. It was mounted below the fuselage and supplied by gravity feed through a vertical discharge pipe.

With a five-brush assembly on the unit, the droplet spectrum obtained with 10 per cent DDT in polymethylnaphthalene and fuel oil emitted at 1.05 gal. per sec. when the aircraft flew at 150 m.p.h. showed a mass median diameter of 195 microns. With a three-brush assembly emitting at 0.58 gal. per sec. the mass median diameter was 180 microns. No droplets were greater than 315 microns in diameter.

Spraying runs were made 300 yd. apart and at a height of 100 ft. When 10 sq. mi. were treated with 10 per cent DDT dispersed by the five-brush assembly, at 0.22 lb. of DDT per acre, an average of 98.7 per cent reduction of adult mosquito population was obtained; the average reduction of black flies was not less than, and probably considerably more than, 80 per cent. When 5 per cent DDT was dispersed by the five-brush assembly over a similar area at 0.11 lb. per acre, the average reduction was 87.4 per cent for mosquitoes and only 24 per cent for black flies. When 20 per cent DDT was dispersed by the three-brush assembly at 0.27 lb. per acre, the average reduction of mosquitoes was 96.5 per cent and of black flies 87 per cent.

The use of the rotary brush in operations against adult mosquitoes has the following advantages over the straight emission pipe formerly used in Canada:

(a) better control: an average of 99 per cent as compared with 85 per cent;

(b) economy in flying time: 3.4 sq. mi. may be treated in one flight as against 1 sq. mi. With lines of flight 300-yd. apart only 6 runs per mile of starting line are required as against 9;

(c) greater simplicity: the application may be made at 100 ft. above terrain at nearly all wind speeds; the flying height needs to be increased only when the cross-wind component falls below 4 m.p.h.;

(d) economy in material: substitution of a 10 per cent for a 4 per cent DDT spray allows considerable economy in the fuel oil used as a diluent.

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Effect of Spittlebug Infestation on Nutritive Value of Alfalfa and Red Clover

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The meadow spittlebug has been a serious pest of legume hay crops in recent years throughout most of the northeastern quarter of the United States. When infestations have been heavy, the insect has caused reductions in the yields of hay. Where control measures have been applied, the resulting hay has been improved in appearance and has led to many statements that the "quality" is improved. During the past three years studies were conducted to determine the effects of spittlebug infestations on the total yield as well as the nutritive value of alfalfa and red clover as measured by the differences in the dry matter, protein, and carotenoid[2] content of the crops from treated and untreated plots.

METHODS AND MATERIALS.—All of the legume samples were selected from replicated field plots of various spittlebug control treatments. Only plots with large differences in spittlebug populations were chosen so that nutritive differences would be detected if any occurred. Reduction in the numbers of the insects was accomplished by the use of proprietary formulations of benzene hexachloride, toxaphene, or chlordane in the spring or DDT in the fall. The materials were applied with power sprayers in a manner similar to that described by Weaver (1951). Where yield records were taken they were obtained by the method mentioned by Weaver (1950).

Spittlebug nymph populations were estimated by counting nymphs per stem or determining the per cent of stems infested. Chamberlin & Medler (1950) have shown that the latter of these methods has a tendency to give overevaluations of the true population. For this reason all of the counts obtained in 1951 and part of those in 1950 were made by counting nymphs per stem.

Plant samples for analysis were cut by hand from several square-foot areas in each replicate of all treatments used. All of the plant material from plots of a given

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[2] Carotenoids refers to a mixture of yellow pigments not pure β carotene. The samples were not run through a chromatographic tower.

Table 1.—Dry matter, protein, and carotenoid content and yield of alfalfa with various populations of spittlebug nymphs.

Test	Date of Treatment	Spittlebug Population	Date of Harvest	Yield of Hay[7]	Date of Sampling	Per Cent Dry Matter	Per Cent Protein	Carotenoid, Mg/G Dry Wt.
1	4–29–49	0	6–7	6465[4]	6–6	24.5	17.5	188
	5–10–49	0	6–7	5739	6–6	25.5	18.0	195
	None	75.0 IS[1]	6–7	4126	6–6	26.5	16.7	158
2	5–12–50	0			5–24	24.0	13.8	171
	5–12–50	25.3 IS			5–24	24.0	14.9	183
	None	66.5 IS			5–24	25.0	13.6	159
3	5–1–51	.01 BS[2]	6–15	7550[5]	6–12	24.2	16.2	145
	4–23–51	1.22 BS	6–15	6763	6–12	24.5	13.3	161
	None	8.65 BS	6–15	6598	6–12	24.5	17.6	145
4	Fall 1950[6]	0.16 BS			6–11	22.0	18.3	214
	None	4.41 BS			6–11	22.0	18.1	196
5	Fall 1950[3]					22.0	14.1	168
	None					22.5	12.4	165

[1] IS = Per cent infested stems.
[2] BS = Spittlebug nymphs per stem.
[3] Same as test 4 except that timothy was not separated from the mixture.
[4] Alfalfa-red clover mixture.
[5] Alfalfa-ladino-timothy mixture.
[6] An application of DDT to the new seeding was made on each of the dates 7-27, 8-10, 9-2, and 9-21.
[7] 20 per cent moisture.

Table 2.—Dry matter, protein, and carotenoid content and yield of medium red clover with various populations of spittlebug nymphs.

TEST	DATE OF TREATMENT	SPITTLEBUG POPULATION	DATE OF HARVEST	YIELD OF HAY[4]	DATE OF SAMPLING	PER CENT DRY MATTER	PER CENT PROTEIN	CAROTENOIDS MG/G DRY WT.
1	4–29–49	0	6–7	6465	6–6	20.2	14.9	206
	5–10–49	0	6–7	5739	6–6	21.5	14.9	202
	None	75.0 IS[1]	6–7	4126	6–6	24.5	14.6	184
2	5–12–50	0			6–14	18.5	14.2	197
	5–12–50	25.3 IS			6–14	19.0	13.5	187
	None	66.5 IS			6–14	19.0	14.9	183
6	5–13–50	0.04 BS[2]	6–14	3200[3]	6–14	22.5	13.3	161
	5–24–50	0	6–14	3199	6–14	22.8	15.2	170
	None	3.28 BS	6–14	2212	6–14	23.8	14.8	161
7	5–8–50	0	6–8	4166	6–8	18.0	15.3	223
	None	69 IS	6–8	2300	6–8	21.1	15.7	216

[1] IS = Per cent infested stems.
[2] BS = Spittlebug nymphs per stem.
[3] Red clover alfalfa mixture.
[4] 20 per cent moisture; harvest in 1951.

treatment was combined and thoroughly mixed. The particular plant desired, alfalfa or red clover, was separated from the mixture and ground in a Hobart food chopper. This chopped material was mixed and samples weighed immediately for dry matter and carotenoid analysis.

Carotenoids were determined by the method described by Hibbs *et al.* (1949). Dry matter was determined by drying duplicate 100 gram samples overnight in an oven maintained at 100° C. These samples were then used for analysis for total nitrogen by the Kjehdahl method. Protein was calculated by multiplying the value for total nitrogen by 6.25.

EXPERIMENTAL RESULTS.—The results of the various analyses for alfalfa are presented in table 1, for red clover in table 2. In these tables "date of treatment" refers to the time that the insecticides were applied. Controls applied too late do not produce as large yield increases as those applied early, so the date of treatment is important. "Date of sampling" refers to the time that the plant material was collected for analyses. "Date of harvest" refers to the time that yield records, if any, were taken. Plots in tests number one and two contained both alfalfa and red clover so that the infestations and yields which were taken on the entire mixture are presented as identical for the two crops in those tests. It should be noted also that the data in tests 4 and 5 are from the same plots. In test 4 the alfalfa was analyzed alone. In test 5 the entire hay mixture, including alfalfa and timothy, was analyzed.

DISCUSSION.—The yield increases of hay mixtures resulting from treatment for spittlebug control ranged from approximately one-half to one ton per acre. The increase of 950 pounds (7550 pounds over 6598 pounds) in 1951 was less than the increases in 1950 and 1949. However, an increase of 1000 pounds per acre is more than enough to justify the cost of treatment.

The percentage dry matter in plants with heavy spittlebug infestations was always equal to or greater than that in plants where spittlebugs were controlled. In alfalfa the percentage dry matter varied from 0.5 to 2.0 greater in the untreated than in the treated. In like manner the percentage dry matter in clover ranged from 0.5 to 4.2 greater in the untreated than in the treated. In both crops the greatest differences occurred in 1949. In a season comparable to 1951 when the growth is rank and heavy, the hay becomes difficult to cure. In such cases higher yields resulting from spittlebug control contribute to difficulty of curing and might be considered a disadvantage.

In most instances the protein content in alfalfa as measured by total nitrogen was somewhat higher in treated plants, although the difference in percentage protein amounted to only 0.2 to 1.7. An exception may be noted in test 3 where the

untreated actually showed more protein than the treated. The greatest increase in per cent protein, 1.7, occurred in the alfalfa-timothy mixture where the increase in alfalfa alone was only 0.2. This indicates that any increased protein content in mixed hays resulting from spittlebug control are probably due to an increase in the proportion of legume in the hay mixture rather than from an increase in the protein content of the legume itself. Since the spittlebug attacks legumes more severely than it does the grasses, this seems to be a logical conclusion.

In red clover, no consistent increases in protein content occurred as a result of spittlebug control.

Carotenoids in alfalfa were increased from 3 to 37 milligrams per gram of dry matter and in red clover from 4 to 22 milligrams following treatment for spittlebug control. However, these relatively minor differences would not justify treatment for the increase in this nutrient alone.

The most striking differences due to treatment of both alfalfa and red clover occurred in 1949. This was true of yield, dry matter, protein, and carotenoid content. Weaver *et al.* (1950) have stated that the effect of the spittlebug is conditioned by the presence of the clover leaf weevil and by growing conditions in the early spring. Since abundant rainfall at the start of the growing season is conducive to good legume growth as well as to the development of a fungus disease which kills the clover leaf weevil, it may be revealing to compare the rainfall in the three years in which these tests were conducted. The inches of rainfall recorded at Wooster for the period April 15 to May 15 were 2.08 in 1949, 4.01 in 1950, and 3.97 in 1951. During the spring of 1949, a dry year, the larvae of the clover leaf weevil were abundant and damaged red clover severely during its early stages of growth. Red clover can recover from this damage if it encounters no further setbacks. The presence of large numbers of sap feeding spittlebugs immediately following damage by the leaf weevil prevents adequate recovery of the clover. Climatic conditions in the 1950 and 1951 season were unfavorable for the clover leaf weevil and exceptionally favorable for early legume growth; as a result the effects of the spittlebug were not as pronounced.

SUMMARY.—Data obtained during three seasons from tests of the effect of spittlebug nymphs on the nutritive value and yield of red clover and alfalfa are presented. Control of the spittlebug resulted in one-half to one ton increase in yields of mixed hay. On a percentage basis, dry matter content of clover and alfalfa was reduced when insects were controlled.

Differences in the nutritive value as measured by chemical analyses for protein and carotenoid content were observed but were not important enough to warrant the statement that spittlebugs significantly reduce the nutritive value of the individual legume in a hay crop. However, marked increases in nutritive value of a mixed hay crop treated for spittlebug control could result from the increased proportion of legume in legume-grass mixtures.

Weather conditions and accumulations of other insect species tend to condition the amount of damage that the spittlebug causes. Good growing conditions and abundant rainfall in the early spring lessen the effect of spittlebugs on the nutritive value of the crop as well as the total crop yield.

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Effects of Sun, Wind and Rain on DDT Dust Residues on Forage Crops[1]

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The reduction of insecticide residues on plants with time can be attributed to several factors. Growth of the plant results in a reduction of the residue on the weight basis, due to an increase in the weight rather than a decrease in the total quantity of insecticide. An actual loss of the insecticide also occurs through a combination of chemical and physical processes usually grouped together under the term "weathering." Sloan *et al.* (1951) studied the relative importance of growth and weathering on the reduction of residues on lettuce and summarized the previous information on the subject, but made no attempt to study the component factors involved in the weathering process. The present report includes a series of experiments designed to evaluate the relative importance of sunlight, wind, and rain in weathering dust deposits of DDT on forage crops in the field, under conditions which largely eliminated the growth factor.

Many of the factors affecting weathering, such as temperature, humidity, light and rain have been investigated, but their relative importance and the mechanism of their action is often uncertain.

The effects of temperature and humidity on DDT deposits and residues were were investigated by Gunther (1945), Sweetman (1945), Burgess & Sweetman (1949) and by Chishom & Koblitsky (1947). These authors came to the general conclusion that high temperatures caused a loss of DDT residues and high humidity accelerated the rate of loss. High temperatures might be expected to cause an increase in the rate, either of chemical degradation or of volatility. The vapor pressure of DDT was reported by Balson (1947) to be 1.5×10^{-7} mm. at 20° C. and 7.2×10^{-7} mm. at 30° C. Dustin *et al.* (1947) reported no indication of residue loss of DDT when testing its effectiveness as a fumigant, while Fleck (1949) considered the prolonged residual action of DDT to be due to its low vapor pressure and its stability to oxidation. Fleck (1944) concluded that the loss of DDT deposits by volatilization occurs too slowly to be of any great importance. It might therefore be concluded that the temperature affects DDT deposits more by chemical than by physical means.

Sunlight may affect deposits of DDT by raising the temperature, the effect of which has just been discussed or by the independent action of its ultraviolet component. The latter has been investigated by a number of workers. Chisholm & Koblitsky (1947) reported that a 20.2 to 22.2 per cent loss of technical DDT dusted on glass slides was effected by 64 hours of mid-summer sunlight. Lindquist *et al.* (1946) and Chisholm *et al.* (1949) also reported that sunlight deleteriously affected the deposits of DDT. Vandramini (1947) reported that an exposure of DDT to one hour of ultraviolet rays caused the same loss of effectiveness to *Drosophila melanogaster* as 30 days of natural light. Most of this work indicates that sunlight and artificial ultraviolet light cause a greater change than the associated temperature change could explain. Gunther & Tow (1946) reported that under field conditions, DDT, may disappear rapidly leaving a residue of almost non-insecticidal dehydrohalogenation product. Later Fleck (1949) reported that ultraviolet light catalyzes the decomposition of DDT which in the presence of air produces 4,4-dichlorobenzophenone. These reports indicate the mechanism by which the effectiveness of DDT residues in the field are reduced.

Work by Fennah (1945) indicates the effectiveness of rain in reducing the residues of DDT. By exposing glass slides sprayed with DDT to 1.6 inches of intermittent rain, progressive erosion of the aggregates was obtained. He suggested that moderate showers may seriously reduce insecticide deposits on the upper surfaces of leaves. It was reported by Hadaway & Barlow (1949) that 0.87 inches of rain during the first 24 hours after an application of DDT wettable powder washed off most of the deposit.

[1] The authors wish to acknowledge the financial support given this project by the Geigy Company, Inc. of New York which made this work possible.

Langford & Squires (1947) reported DDT-sprayed grape leaves remained effective against Japanese beetles 15 days and 4 rains after an application of wettable powder. Gunther *et al.* (1946) and Ginsburg *et al.* (1949) also reported on the effects of rain on insecticide deposits. Kirk (1951), by simulating rainfall with overhead irrigation, investigated the effects of rain on DDT spray deposits on potatoes. He reported that 0.5 inches of water applied just after drying of a spray of DDT wettable powder removed 86.4 per cent of the initial deposit but, if the water was not applied until 24 hours or more after spray applications, the residues were much less susceptible to erosion. All evidence points to an almost entirely mechanical effect of the rain.

As far as is known, no data have been reported on the effects of the wind in removing insecticide deposits.

From the above discussion of the effect of the chemical reactions and physical losses of DDT residues, it is obvious that each factor alone shows a moderate but important effect in most cases. In the field all factors of weathering (Sloan *et al.* 1951) acting together cause a rapid reduction of the residue, especially at optimum conditions.

The data reported herein are the results of the work of two summers on the effects of the principal components of weathering on the residues of DDT dust on forage crops. Although time did not permit replication of the tests, the results were consistent enough to furnish good preliminary conclusions. No allowance was necessary for growth (since growth was almost complete at the time the tests were initiated) and no attempt was made to differentiate between the chemical and physical mechanisms. An attempt was made to evaluate the effects of each component separately and in combination with each of the others.

PROCEDURE.—A strip of red clover, which had almost completed its growth was dusted with a 5 per cent ribbon mill mixed DDT dust. This dust was applied with an even-feed power forage duster at a rate of approximately 8 pounds of actual DDT per acre. This rate was much heavier than ordinarily is applied to forage crops, but in order to retain a fairly large amount of residue on the crops after each sampling interval, the heavier rate was used. The treated strip consisted of an area 10 feet wide by 80 feet long. Immediately after dusting, previously constructed cages were set over the dusted clover. All of the cages, which are described below, were 4 feet square by 2 feet high and were constructed as follows:

(1). For study of exposure to the sunlight only, a cage was completely enclosed with sheets of cellulose acetate, with all seams sealed to prevent rain and wind from entering

(2) In order to expose the treated plants to the sunlight and the rain a cage was constructed that had the sides covered with cellulose acetate, while the top was left open. This eliminated most of the wind but allowed the sunlight and rain to enter.

(3). For exposure to the sunlight and the wind, the cage had no sides, but the top was covered with cellulose acetate and was extended with cellulose acetate eaves which were about 10 inches wide and projected downward at an angle of 65 degrees. Such an arrangement allowed the wind to blow into the cage but prevented the rain from entering.

(4). For exposure to the rain, a cage with an opaque removable top was constructed. The sides of the cage and the removable top were covered with waterproof roofing paper. Late each evening and on cloudy days the top was removed allowing any rain that might fall to enter the cage. Sufficient light entered under these conditions to keep the clover in a reasonably healthy condition.

(5). In order to study the effects of the wind and the rain, the cage was constructed with an opaque removable top the same as the previous cage. Eaves, approximately 12 inches wide, projected down at a 65 degree angle. Such an arrangement permitted the wind to enter the cage but excluded the sun. The top was removed and replaced at the same time as the previous cage.

(6). For exposure to the wind, the cage consisted of a fixed top of roofing paper with eaves similar to the ones described above. Such a construction prevented any sun or rain from entering the cage but allowed the wind to blow freely through.

(7). An area in the treated strip that was marked off with stakes into a four foot square was the plot that was exposed to all of the weathering factors. All

Table 1.—The average amount of each weather component to which the treated clover was exposed. Minetto (Oswego Co.), N. Y.

Conditions of Exposure	Sampling Interval in Days		
	7	14	24
Rain (inches)	0.24	0.72	1.64
Sunshine (total hours)	62.17	121.03	160.09
Wind (avg. mph.)	6.2	8.2	6.5

samples of completely weathered clover were taken from this area.

Samples of the treated clover were taken at the time of application and 7, 14 and 24 days later. The samples consisted of two square feet of the standing hay. The samples were weighed and placed in 2-gallon jars with 250 or 500 mls. of benzene, depending on the sample size. The jars were then rotated end over end for 15 minutes. The benzene strippings were placed in bottles that were stoppered with corks wrapped with tin foil.

The samples were analyzed by the colorimetric method of Schechter *et al.* (1945), as modified by Downing & Norton (1951) and after the chromatographic treatment of Norton & Schmalzreidt (1951).

RESULTS.—The amounts of each weather component available during the test periods to affect the residues are recorded in table 1, giving the average accumulated totals at the end of each sampling interval. None of the factors deviated greatly from the normal weather conditions in northern New York.

The results of the chemical analysis are summarized and presented in table 2. These data are the average residues obtained from the results of the two years study. Each figure is the average of two chemical analyses made from samples taken from each yearly test. The residues in parts per million were calculated from the green weights of the samples.

The percentage losses of the initial deposits are recorded in table 3 and plotted in figure 1 to indicate more clearly the magnitude of each single factor and combination of factors.

DISCUSSION.—In these tests rain appeared to be the most important individual factor in eliminating DDT dust deposits on forage crops during the first week after application. Where 0.24 inches

Table 2.—DDT residues on clover exposed to different weathering factors. Minetto (Oswego Co.), N. Y.

Conditions Exposure	Residue in ppm.: Interval in Days[1]		
	7	14	24
Rain only	38	50	58
Sun only	181	134	89
Wind only	115	81	57
Sun plus rain	78	39	13
Sun plus wind	192	77	24
Rain plus wind	50	55	56
Rain plus wind plus sun	27	8	2

[1] Initial deposit was 305 ppm.

of rain fell during the first week 83 per cent loss of the initial deposit was attributed to this weather component. This loss is approximately 25 per cent greater than the loss attributed to the wind during the same period of time and is about two and one half times greater than the loss effected by the sunlight. However, after this large initial loss of insecticide the rains occurring during the rest of the test periods gave no measurable effect. This agrees with other observations of the authors and others, that the time the rain falls on DDT deposits is more important in reducing the residues than the amount that falls; *i.e.*, a light shower may cause a greater loss of insecticide during the first week than a heavy rain falling some time after the deposit has weathered for 7 to 10 days. It also indicates that the rain tends to remove the less strongly adherent material and has much less effect on the persistent material remaining.

A total of 62.17 hours of sunlight was available to the treated plants during the first week of the test and a loss of approximately 36 per cent was attributed to this

Table 3.—The per cent loss of the initial DDT deposit when exposed to various weather components. Minetto (Oswego Co.), N. Y.

Conditions of Exposure	Per Cent of Initial Deposit Lost at the End of Each Sampling Interval		
	7	14	24
Rain only	87	82	80
Sun only	39	54	70
Wind only	61	72	80
Sun plus rain	73	86	95
Sun plus wind	35	73	91
Rain plus wind	83	81	81
Rain plus sun plus wind	90	97	98

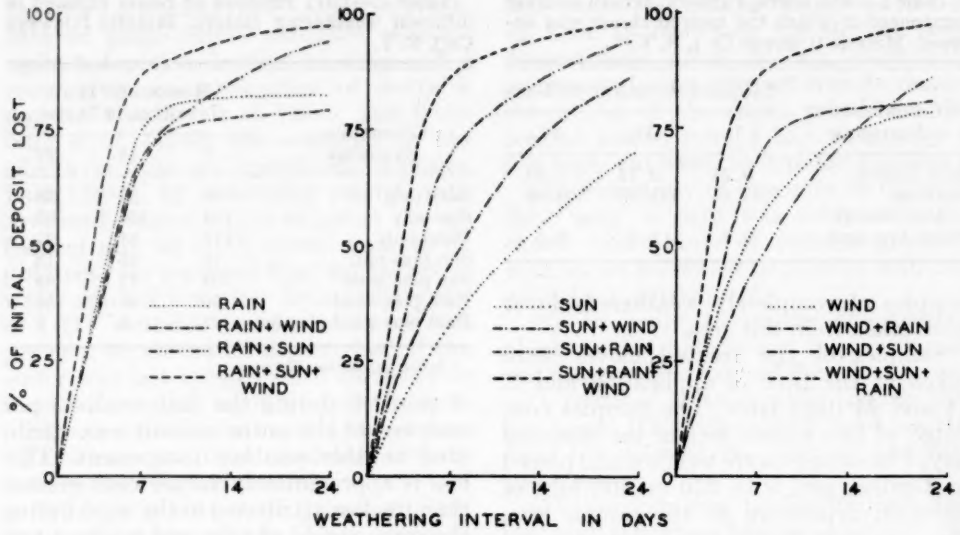

Fig. 1.—The loss of DDT dust deposits attributed to each weather component. Oswego county, N. Y.

amount of sunlight. This initial loss may seem low when compared with the loss of residue from the other factors but the greatest importance of the sunlight lies in the continued degrading influence on the deposits during the succeeding weeks, which is apparent from figure 1. At the end of 24 days the total loss due to the sun alone approached that from the other factors. Sunlight does not appear to be a speedy factor in eliminating the residue of DDT but it is a very important weathering component in eliminating the residues on forage crops over long periods. It is probable that the ability of the ultraviolet light to affect the persistent residue as well as the loosely adhering material accounts for its continuous degrading action.

The loss effected by the wind was greater than the initial loss caused by the sun but not as great as the loss attributed to the rain. In this test an average wind of 6.2 mph caused a loss of approximately 60 per cent of the original deposit. At the end of an exposure of one week to the wind, the rate of loss began to level off (Fig. 1) but not as rapidly as the loss due to the rain. At the end of 24 days the wind has caused a loss of the initial deposit about equal to the loss due to the rainfall at the same time. These data suggest that the wind, like the rain, affects the less strongly adherent material of the deposit by mechanically removing it. However, the more continuous loss due to the wind is probably caused by the rubbing of the plant surfaces against each other in a manner suitable to eliminating some of the more persistent residue on the plant surfaces. In this manner the loss due to the wind may eventually equal the loss attributed to the rain.

Since the individual weather components show a high loss of DDT deposits, it might be assumed that the interaction of any two factors would cause a larger loss of the deposit. In some cases this was found to be true while in others very little additive effect was found by the combined action of two factors.

Previous discussions indicated that either the rain or the wind caused a rapid loss of the deposit soon after application but was much less effective during the succeeding weeks. The interaction of the rain and wind was slight, presumably because either tends to remove mechanically the same less strongly adherent material. In examining figure 1 or table 3, it becomes evident that there is little difference in the loss caused by the rain alone and by the rain and wind in combination.

The rain and the sun appeared to be the most effective combination in reducing insecticide residues on forage crops (Fig. 1). Their effects on the deposits were approximately additive. It is assumed that the sunlight, as previously discussed, can

act on the residue remaining on the plants after the rainfall has had its effect.

The interaction of the sun and wind is similar to that of the rain and sun. This would be expected from the similar action of the rain and wind alone. Figure 1 shows about 75 per cent of the original deposit is lost in 2 weeks due to the combined action of the sun and wind while about 90 per cent is lost in 24 days. Since neither of these factors, when investigated alone gave high losses, it is interesting that the combination becomes so effective in eliminating DDT residues. The large percentage of residue loss due to the interaction of sunlight and wind may be very important in eliminating residues of DDT in arid regions or areas of prolonged drought.

The effect of all three weathering components together is somewhat greater than that of any two, but not outstandingly greater than that of the sun with either rain or wind, as might be inferred from the previous discussion.

The foregoing discussion applies to dust deposits only and it should not be assumed that deposits of other formulations would react in the same manner under similar conditions.

SUMMARY.—An investigation of the effects of the weather components on DDT dust residues are reported. By using specially constructed cages, which were placed over heavily dusted clover, the weathering action of the sun, wind and rain, separately and in combination were studied. The loss of the initial deposit attributed to each of these weathering actions was compared. It was found that either wind or rain caused a rapid loss of the deposit soon after application but are much less effective during the succeeding weeks. The combined effects of the wind and rain are less effective than might be inferred from their separate effects, presumably because either tends to remove mechanically the same less strongly adherent material. Sunlight causes a slower initial loss of the deposit than either rain or wind, but its degrading effect continues indefinitely. Sunlight in combination with either rain or wind is more effective than is suggested by its separate effect, because it is capable of reducing the more adherent residue not affected by the other factors.

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Control of a Dipterous Leaf Miner on Tomatoes in California

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A dipterous leaf miner, *Liriomyza* sp., was first observed by the authors on tomatoes in southern California in 1939. Although the insect was evident in that and succeeding years, the damage it caused was considered to be of minor importance. In 1945 cucumbers, muskmelons, winter and summer squash, the wild buffalso gourd (*Cucurbita foetidissima* H.B.K.), various weeds of the amaranth family, and tomatoes were attacked in coastal areas.[1] The infestation on cucurbits was considered serious, with lighter infestations on peppers and tomatoes, except in one field of tomatoes that was heavily infested. In 1946 and 1947 tomatoes in the coastal areas were infested, and in 1947 some growers estimated that their crops were reduced 25 to 50 per cent. Heavily infested fields were observed in San Diego, Orange, and Los Angeles Counties, and infestations were reported from Santa Barbara County. In 1948 experiments were begun in southern California by the authors to develop methods of insecticidal control, and the observations and experiments made in this area from 1948 to 1951 are reported in this paper.

During 1948 the infestation was severe inland as well as in coastal areas. In 1949 and 1950 the infestation in both areas was late in relation to crop development, so there was little damage. In 1951 damage occurred in both areas:

Damage to the plants from leaf miner attack results from a devitalizing effect due to the loss of leaf surface and leaves. The lower or middle leaves are usually attacked first, and when severely mined they turn yellow and drop from the plants. This damage is more noticeable on tomatoes grown on poles than on field-grown tomatoes. The lower 2 or 3 feet of the vines on poles have been observed to be completely devoid of foliage. This loss of foliage also exposes the fruit to the sun, and a larger percentage of the fruit is lost from sunburn than on normal plants.

In tests on peas for the control of *Liriomyza flaveola* (Fallen), Smith & Lange (1946, pp. 52–54) found lead arsenate and DDT dusts to be fairly effective; Lange and Smith (1947) reported that 5 per cent chlordane dust was more effective than TDE, DDT, benzene hexachloride, or methoxychlor for the control of *L. orbona* (Meig.). Wolfenbarger (1947) stated that chlordane sprays were more effective than sprays of BHC, nicotine sulphate, hexaethyl tetraphosphate or DDT on potatoes for the control of *L. pusilla* (Meig.). According to Jefferson & Pence (1948) chlordane sprays and BHC dusts were effective against *L. flaveola* on asters. They also obtained promising results with toxaphene and parathion sprays. Hayslip (1948) found parathion sprays to be most effective on celery, and on tomatoes parathion sprays gave the best results, closely followed by toxaphene sprays. Jefferson & Eads (1949) suggested the use of toxaphene sprays or chlordane or BHC sprays and dusts for the control of *L. flaveola* on asters. In 1950, R. N. Jefferson, of the University of California at Los Angeles, reported to the writers that the aster growers in Los Angeles County were obtaining excellent control of *L. flaveola* with 1 per cent parathion dust applied weekly at the rate of about 15 pounds per acre.

Some tomato growers believe that the use of DDT for the control of other tomato insects is the reason for the increase in the number of leaf miners on that crop in recent years. Michelbacher *et al.* (1949) report that the widespread use of DDT and TDE in northern California may have caused the increase in this and other normally unimportant pests on tomatoes. This does not appear to be true in southern California, where infestations of the leaf miner became serious in several areas before DDT came into general use. However, O. A. Hills, of the Bureau of Entomology and Plant Quarantine, reported in 1950 (personal communication) that, in experiments conducted on melons in Arizona, DDT-treated plots were more heavily infested than untreated plots and that all insecticides used in his experiments reduced the number of parasites.

[1] Observations in 1945 made by John C. Elmore, Bureau of Entomology and Plant Quarantine.

EXPERIMENT IN 1948.—*Small Plot Tests.*—In these tests small plots, 5 and 6 rows wide (rows 5 to 8 feet apart) and 50 to 60 feet long, were used in five fields. Each field contained four replicates arranged in randomized blocks. Dusts were applied with rotary hand dusters, and concentrated sprays with a proprietary pressure sprayer. Three applications were made at weekly intervals on the small plants, before fruit setting, and three applications at 2-week intervals after fruit setting, the latter three being the normal schedule for tomato fruitworm control.

Some leaf miner control was apparent from the use of dusts containing 20 per cent of toxaphene, sufficient BHC to contain 2 per cent of the gamma isomer, 2 per cent of lindane, or 10 per cent of chlordane. Little or no control was obtained with 10 per cent dusts of methoxychlor, TDE, or DDT. Of the concentrated sprays, applied at the rate of about 2 gallons per acre, lindane was the most effective, followed by toxaphene, chlordane, and DDT in the order named.

The four most promising materials used in the early tests (toxaphene, BHC, lindane, and chlordane) were used in a late field of tomatoes, both as dusts and as concentrated sprays. Nine applications were made at weekly intervals, the first three prior to fruit setting when the plants were small and the last six after fruit setting over the normal period for making applications for tomato fruitworm control. Four counts were made in the field on September 9, 15, and 29, and October 15, with 40 to 260 leaflets being counted per plot.[1] The treatments were replicated four times in a randomized block arrangement. The results are shown in table 1.

Fair control of the leaf miner was obtained with most materials, but when the number of applications are taken into consideration, the results were not very encouraging. Excellent control (about 90 per cent) of associated infestations of the tomato fruitworm was obtained with the toxaphene sprays and and dusts, and fair to good control (71 to 85 per cent) with the other materials. Some burning on the margins of the leaves resulted from the use of the BHC spray.

Large-Scale Tests.—A steam-generator sprayer equipped with a boom so that three rows of tomatoes could be treated at one time with two nozzles per row was used on a late field of tomatoes.[2] Two applications were made on September 28 and October 7 to plots averaging 1.5 acres in size, arranged at random with four replicates. An untreated check plot was not replicated. From 12 to 14 gallons of spray were applied per acre per application. The sprays were prepared from wettable powders containing 25 per cent of lindane, 40 per cent of chlordane, and 25 or 40 per cent of toxaphene. The results of the test are given in table 2.

Table 1.—Effect of several insecticides, applied as dusts or concentrated sprays, in reducing the mines of a dipterous leaf miner on tomatoes, 1948.

INSECTICIDE (PER CENT BY WEIGHT	DUST OR SPRAY APPLIED PER ACRE FOR THE SEASON	MINES PER LEAFLET	REDUCTION IN LEAF MINES
	Pounds	*Number*	*Per Cent*
Dusts (including 25 per cent of sulfur in pyrophyllite):			
Toxaphene 20	164	0.53	65
Chlordane 10	166	.62	59
BHC 2	167	.63	58
Lindane 2	164	1.01	33
Sprays:	*Gallons*		
Lindane 2.5	18	0.40	74
Toxaphene 5	19	.43	71
Chlordane 2.5	19	.76	50
GHC, gamma isomer 2.5	18	.79	48
Check	—	1.51	—
Difference for significance at odds of 19 to 1		0.65	

On the basis of counts of leaf miner adult sweepings made 1 day previous to the first application and continued at regular intervals until 2 weeks after the second application, from good to excellent control was obtained with all treatments. Leaf-mine counts made 2 weeks after the second application showed the best results with lindane (Table 2).

EXPERIMENTS IN 1949.—In 1949 experiments were conducted in three fields of about 20 acres each. There were five to seven replicate plots in each field, and each plot ranged from 0.5 to 0.67 acre in

[1] Lauren D. Anderson, University of California Citrus Experiment Station, and R. N. Jefferson, University of California at Los Angeles, assisted in making these counts.

[2] This experiment was made in cooperation with L. D. Anderson, University of California Citrus Experiment Station, Riverside, with the Bes-Kil Corp., Richmond, Calif., and with the San Diego Fruit and Produce Co.

Table 2.—Control of a dipterous leaf miner on tomatoes from the use of several insecticides applied with a steam-generator sprayer, at the rate of 24 to 28 gallons of spray for the season, 1948.

Insecticide	Toxicant per Acre	Reduction in Adults	Mines per Leaflet	Reduction in Mines
	Pounds	*Per Cent*	*Number*	*Per Cent*
Lindane	0.6	95	2.5	82
Toxaphene	1.5	89	4.0	68
Chlordane	1.4	88	4.2	70
Difference required for significance at odds of 19:1	—	[1]	1.4	—
Check (untreated)	—	—	13.3	—

[1] Not significant by the F test.

size. Three applications of insecticide dusts were made at 2-week intervals, at the rate of about 30 pounds per acre per application, beginning at fruit-setting time. No undusted plots were included in these experiments, the 10 per cent DDT plots serving as the checks.

DDT, 5 or 2 per cent, was added to several of the insecticides to make them more effective for the control of associated infestations of the tomato fruitworm. Toxaphene, 10 per cent, and parathion, 2 per cent, were dropped from the experiment in the third field because they were relatively ineffective against the tomato fruitworm. In southern California the tomato fruitworm is the most serious pest of tomatoes, and a control program for other pests must be effective against this species.

Infestation of the leaf miners was light in 1949 in all fields and no damage was apparent. In the first field the infestation was too light to warrant infestation counts. The data in table 3 show the results from field 2 (5 replicates) and from fields 2 and 3 combined (12 replicates). Chlordane and toxaphene were significantly better than DDT, but the differences were so small that the general results were not encouraging.

Experiments in 1950.—In 1950 three experiments were conducted, one with sprays and two with dusts. All the tests were made in three fields, on small plots the size of those used in 1948. The dusts were applied with hand dusters and the sprays with a power sprayer. Unless otherwise stated, each treatment was applied three times, at 2-week intervals, on each plot.

Sprays.—All the sprays were made with wettable powders except schradan. The strengths and dosages used, together with the results obtained, are given in table 4. The sprays were applied at the rate of 30 to 40 gallons per acre per application. Adding sugar to the insecticide did not increase the value of the spray, as the results were almost identical.

Table 3.—Comparison of several insecticide dusts applied at the rate of 90 pounds per acre for the season, on the control of a dipterous leaf miner on tomatoes, 1949.

Insecticides (Per Cent by Weight	Mines per Leaflet	
	Field	Fields 2 and 3
Chlordane 5 plus DDT 5	1.5	0.9
Toxaphene 20	1.5	.9
Toxaphene 10 plus DDT 2	1.6	.9
Aldrin 1 plus DDT 5	1.8	1.2
DDT 10	2.3	1.4
Difference required for significance at odds of 19 to 1	[1]	.3
Toxaphene 10	1.6	
Parathion 2	[1]	

[1] Difference not significant by the *F* test.

Of the materials used in both fields, dieldrin and EPN gave good to fair control, whereas chlordane, DDT plus schradan, and toxaphene gave only fair to poor control.

In field 1 toxaphene gave good control, but in field 2 it gave no control, either with or without sugar. No explanation can be offered for this failure of toxaphene in 1950, as it had been one of the most promising materials for leaf miner control in previous tests. Good to excellent control of tomato fruitworm was obtained with these toxaphene sprays, so the poor results on leaf miner cannot be attributed to faulty application.

Dusts.—In the first experiment the dusts were applied at the rate of about 30 pounds per acre per application. Each treatment was replicated four times.

Table 5 shows that at the strengths used good control was obtained with aldrin, fair control with dieldrin, some control with EPN or toxaphene, and little or no control with compound 1189 (an oxygenated dimer of hexachlorocyclopentadiene compound), DFDT CS-708, or toxaphene plus DDT. Toxaphene alone gave no control in field 1 and fair control in field 2.

Excellent control of the tomato fruitworm was obtained with the toxaphene-DDT combination and with the toxaphene alone; good control with a nitro-

Table 4.—Effect of several insecticides, applied as sprays, on the control of a dipterous leaf miner on tomatoes, 1950.

Insecticide (Quantity in 40 Gallons of Water)	Quantity Applied per Acre for the Season		Mines per Leaflet			Reduction in Leaf Mines Per Cent
	Pounds Toxicant	Gallons Spray	Field 1	Field 2	Average	
Dieldrin (25%) 6 lb.						
With sugar 10 lb.	3.6	95	0.05	0.12	0.08	87
Without sugar	4.3	115	—	.05	—	—
Chlordane (40%) 7.5 lb.						
With sugar 10 lb.	7.9	105	.28	.31	.29	54
Without sugar	9.0	119	—	.27	—	—
Toxaphene (40%) 7.5 lb.						
With sugar 10 lb.	7.5	100	.11	.72	.42	34
Without sugar	9.3	124	—	.74	—	—
EPN (27%) 2 lb.	1.6	120	.08	.14	.11	83
DDT (50%) 6 lb. plus Schradan[1]	0.4	103	.23	.44	.34	47
Difference required for significance at odds of 19 to 1	—	—	[2]	.33	[2]	
Check		—	.59	.68	.64	
Difference required for significance at odds of 19:1	—	—	.24	.31	.22	

[1] One gallon of a product containing 4 lbs. Schradan.
[2] Not significant by *F* test.

paraffin derivative, compound 1189, dieldrin, and aldrin; and only fair control with DFDT and EPN.

The second dust experiment was started after the grower had made one application of a dust containing 15 per cent of toxaphene and 5 per cent of DDT, and after it was known that aster growers in Los Angeles County were obtaining excellent control of leaf miners with parathion dusts applied at weekly intervals. Two applications of dust were made at 2-week intervals at 30 pounds per acre each, or four applications at weekly intervals at 15 pounds per acre each. Each treatment was replicated six times.

Table 6 shows that (1) poor results were obtained with 5 per cent of malathon applied at 2-week intervals, (2) excellent control with either 1 or 2 per cent of parathion plus 5 per cent of DDT applied at weekly intervals at 15 pounds per acre, and (3) only fair to poor results with applications at 30 pounds per acre at 2-week intervals.

EXPERIMENTS IN 1951.—In 1951 three

Table 5.—Effect of several insecticides, applied as dusts, in reducing the mines of a dipterous leaf miner on tomatoes, 1950.

Insecticide (Per Cent by Weight)	Pounds of Dust Applied per Acre for the Season	Mines per Leaflet			Per Cent Reduction in Leaf Mines
		Field 1	Field 2	Average	
Aldrin 5	96	0.13	0.15	0.14	78
Dieldrin 2.5	93	.23	.13	.18	70
EPN 2	94	.40	.34	.37	40
Toxaphene 20	91	.74	.34	.45	27
Compound 1189 10	93	.41	.65	.53	15
DFDT 10	95	.59	.62	.61	3
CS-708 5	92	.74	1.01	.88	—
Toxaphene 10 plus DDT 5	96	.79	.61	.70	—
Check	—	.46	.79	.62	—
Difference required for significance at odds of 19:1	—	.38	.45	.29	

Table 6.—Control of a dipterous leaf miner on tomatoes with insecticides used as dusts, 1950.

Insecticide (Per Cent by Weight)	Application Interval Weeks	Pounds Dust Applied per Acre for the Season[1]	Mines per Leaflet	Per Cent Reduction in Leaf Mines
Parathion 1 plus DDT 5	1	60	0.23	92
	2	61	1.50	46
Parathion 2 plus DDT 5	1	64	.15	95
	2	60	.77	72
Malathon 5	2	58	2.28	18
Check	—	—	2.77	—
Difference required for significance at odds of 19:1	—	—	.58	—

[1] Total for four applications at weekly intervals, or, two applications at 2-week intervals.

experiments were conducted, two with dusts and one with sprays. All the tests were made in two fields on small plots similar in size to those used in 1948 and 1949. The dusts were applied with rotary hand dusters and the sprays with a high-pressure concentrate sprayer.

Dusts.—In the first test the most effective materials from the 1949 season were applied at weekly intervals at about 15 pounds per acre for a total of five applications, or at 2-week intervals at about 30 pounds per acre for a total of three applications; 10 per cent DDT applied at 30 pounds per acre at 2-week intervals for a total of three applications was used as a check. The results are shown in table 7.

All materials were superior to DDT.

Table 7.—Effectiveness of several insecticide dusts applied at 1- and 2-week intervals in comparison with 10 per cent DDT applied at 2-week intervals in the control of a dipterous leaf miner on tomatoes, 1951.

Insecticide (Per Cent by Weight)	Application Interval Weeks	Pounds Dust Applied per Acre for the Season	Mines per Leaflet	Reduction in Leaf Mines
Parathion 2 plus DDT 5	2	87	0.17	85
	1	74	.08	92
EPN 2 plus DDT 5	2	87	.22	81
	1	74	.16	86
Aldrin 5	2	91	.14	87
	1	72	.24	78
Dieldrin 2.5	2	91	.24	78
	1	70	.36	67
Difference required for significance at odds of 19:1	—	—	.14	—
DDT 10	2	89	1.10	0
Difference required for significance at odds of 19:1	—	—	.21	—

Table 8.—Effectiveness of several insecticide dusts applied at 2-week intervals in the control of a dipterous leaf miner on tomatoes, 1951.

Insecticide (Per Cent by Weight)	Pounds Dust Applied per Acre for the Season	Mines per Leaflet	Per Cent Reduction in Leaf Mines
Heptachlor	87	0.14	85
Compound 711 1	85	.47	51
Compound 269 1	87	.52	46
Toxaphene 20	85	.60	38
Metacide 2	88	.63	35
Compound 1189 10	87	.79	18
Malathon 5	88	.82	15
DDT 10	92	.97	0
Q-137 5	87	1.17	0
Difference required for significance at odds of 19:1	—	.41	—

Parathion 2 per cent plus DDT, 5 per cent, EPN 2 per cent, plus DDT 5 per cent, and aldrin, 5 per cent, were superior to dieldrin, 2.5 per cent. When applied at 2-week intervals, aldrin and dieldrin gave control superior to that obtained with the same materials applied at weekly intervals. Parathion-DDT and EPN-DDT gave better control when applied at weekly intervals than when applied at 2-week intervals, but the difference was not significant.

The second dust experiment was a comparison of several insecticides applied at 30 pounds per acre-application, at 2-week intervals for a total of three applications. The results are shown in table 8. Heptachlor 5 per cent gave the best results in this test, and was superior to all

Table 9.—Effectiveness of several insecticide emulsions applied at 10-day intervals in control of a dipterous leaf miner on tomatoes, 1951.

Insecticides (Pounds per Gallon)	Dilution	Pounds Toxicant per Acre	Mines per Leaflet	Per Cent Reduction in Mines
DDT 2 plus parathion 0.4	1–4	8 1.6	0.10	95
Metacide 3	1–19	3	.18	92
Compound 269 0.5	1–9	1	.39	83
Compound 711 0.5	1–9	1	.44	81
Aldrin 2	1–9	4	.64	72
Heptachlor 2	1–9	4	.64	72
Dieldrin 2	1–19	2	.74	68
Toxaphene 8	1–9	16	1.30	43
Compound 1189 2	1–4	8	1.87	19
Malathon 4	1–19	4	1.95	15
Q-137	1–9	4	2.28	1
DDT 2	1–4	8	2.30	0
Difference required for significance at odds of 19:1	—	—	.57	—

materials used except compounds 711 and 269, each used at 1 per cent.

Sprays.—Four applications of sprays were made at about 10-day intervals at 5 gallons per acre per application. The results are shown in table 9.

DDT-parathion and Metacide gave excellent control; compounds 711 and 269 gave good control; heptachlor, aldrin, and dieldrin gave fair control; and toxaphene, malathon, compound 1189, Q-137, and DDT gave poor control. When the materials giving poor control are eliminated from the analysis, DDT-parathion is superior to 711, heptachlor, dieldrin, and aldrin; and metacide to heptachlor, dieldrin, and aldrin.

SUMMARY.—Results of tests and observations on a dipterous leaf miner, *Liriomyza* sp., on tomatoes in southern California are reported herewith. In 1948, experiments indicated that toxaphene, BHC, lindane, and chlordane were more effective than DDT for the control of this insect. In 1949 large-scale tests showed that dusts containing toxaphene alone or chlordane, toxaphene, or aldrin plus DDT were superior to those containing DDT alone. Dusts containing 10 per cent of toxaphene and 2 per cent of parathion were not considered promising for use on tomatoes because they gave poor control of the tomato fruitworm.

In 1950 concentrated sprays of dieldrin and EPN gave good control, chlordane gave fair control, and DDT plus schradan and toxaphene gave poor control. The addition of sugar to toxaphene, chlordane, and dieldrin sprays did not increase their effectiveness. Dust experiments showed good control with 5 per cent of aldrin, fair control with 2.5 per cent of dieldrin, poor control with 2 per cent of EPN and 20 per cent of toxaphene; and little or no control with 10 per cent of compound 1189, 10 per cent of DFDT, 5 per cent of CS-708, and 10 per cent of toxaphene plus 5 per cent of DDT. In another experiment poor results were obtained with malathon at 5 per cent, but outstanding control (better than 90 per cent) was obtained with 1 and 2 per cent parathion dusts when applications were made at weekly intervals at the rate of 15 pounds per acre. Only fair to poor results were obtained with the same materials at 30 pounds per acre at 2-week intervals.

In the 1951 dust tests, 5 per cent of DDT plus 2 per cent of parathion, 5 per cent of DDT plus 2 per cent of EPN, 5 per cent of aldrin, and 2.5 per cent of dieldrin gave excellent to fair control. DDT-parathion and DDT-EPN gave better results when applied at weekly intervals, and aldrin and dieldrin gave better results when applied at 2-week intervals. In a second experiment 5 per cent of heptachlor gave the best results, followed by 1 per cent of compounds 711 and 269, 20 per cent of toxaphene, 2 per cent of Metacide, 10 per cent of compound 1189, 5 per cent of malathon, 10 per cent of DDT, and 5 per cent of Q-137. Spray concentrates applied at 5 gallons per acre per application in four applications at 10-day intervals gave excellent control with DDT-parathion and metacide, and good control with compounds 711 and 269, fair control with heptachlor, aldrin, and dieldrin, and poor control with toxaphene, compound 1189, malathon, Q-137, and DDT.

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Systemic Poisons on Vegetable Crops

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Gerhard Schrader (1947) working in Leverkusen, Germany reported octamethylpyrophosphoramide to be an effective systemic insecticide—a chemical substance which upon absorption by a plant is translocated in the sap stream to other plant parts rendering them toxic to certain mites and insects. Since that time considerable experimentation involving the so-called systemic poisons has been under way in Germany, England and the United States (Bronson & Dudley 1951; Ivy *et al.* 1950; Wallace 1951).

In addition to originating octamethylpyrophosphoramide known as schradan Schrader has more recently developed a systemic trialkyl thiophosphate commonly known as Systox. It is reported in unpublished data from the distributor that Systox kills by contact and fumigation action as well as by systemic action.

In England, Ripper *et al.* (1949, 1951) reported both field and laboratory investigations with systemics. They have pointed out that one of the great advantages of a systemic poison is its ability to control harmful insects and mites while their predators and parasites are left unharmed. Systox, when applied as a spray, loses this advantage during the initial kill period because of its contact and fumigation action. Schradan, however, kills only by systemic action.

MATERIALS AND METHODS.—During the summer of 1951 the authors studied the effectiveness of schradan (an emulsion concentrate containing 45 per cent active ingredient) and Systox (an emulsion concentrate containing 32.1 per cent active ingredient) in the control of certain species of mites, aphids and leafhoppers on vegetable crops. DDT, parathion and malathon were included in some of the tests for comparative purposes.

The experiments were conducted on plants growing in the field under conditions of natural infestation. All treatments were replicated three to five times in randomized blocks. The materials were sprayed on the foliage by means of either a knapsack sprayer or a power-operated wheelbarrow sprayer equipped with a hand boom. Thorough coverage was obtained by spraying the plants until runoff occurred.

Experiments conducted by the junior author during the past four years have shown that the application of chlorinated hydrocarbons, especially methoxychlor, tends to encourage a build-up in aphid and two-spotted mite populations. These pests are reported to be very susceptible to systemic toxins. In order to provide a constant source of aphids and mites for reinfesting systemically-treated plants, certain plots in several of the experimental plantings were sprayed with methoxychlor during the periods in which systemic materials were being tested. This produced high and uniform aphid and mite populations on plants adjacent to the systemically-treated plots and permitted more accurate comparisons between treated plots since aphids and mites were always present to reinfest plants that were losing their toxicity.

Insect and mite populations were determined by counting the number on 10 leaves selected at random from each plot. Leafhopper nymphs and aphids were counted in the field. Sample leaves infested with mites, however, were taken to the laboratory and counts were made under the microscope.

EXPERIMENT ON TURNIPS.—The objective of this experiment was to compare the efficiency of Systox with schradan in the control of the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis), by varying the concentration of the spray materials and the number of spray applications as shown in table 1. The rates at which the materials were used represent a dilute and a concentrated solution for both schradan and Systox. It should be pointed out, however, that the amount of active ingredient in the concentrated solution of schradan as used was over five times that contained in the concentrated solution of Systox.

Results of the various treatments given in table 1 show that: (1) one application of schradan 4–100 was almost equal to two applications of schradan 0.5–100; (2) one application of Systox 1–100 was only slightly better than one application of Systox 0.5–100; (3) two applications of Systox 0.5–100 were superior to one of Systox 1–100; (4) one spraying of Systox 0.5–100 gave better results than one

spraying of schradan of similar concentration although two sprayings of schradan 0.5–100 proved superior to two sprayings of Systox of similar concentration.

The data indicate that a small amount of Systox, when applied to young turnips, gives good aphid control for approximately two weeks. Schradan requires higher concentrations than Systox to effect good aphid control although it appears to have better residual action than Systox when similar concentrations are compared.

Table 1.—Results obtained when systemic materials were applied to young turnips.

Materials[1]	Pints per 100 Gals.	Dates	Aphids per Leaf August 14	Aphids per Leaf August 23	Yield per Plot[2]
Schradan	4.0	7-20, 8-1	15	25	119.0 lbs.
Schradan	4.0	7-20	140	420	70.5
Schradan	.5	7-20, 8-1	115	480	71.0
Schradan	.5	7-20	650	1600	31.5
Systox	1.0	7-20, 8-1	20	140	96.0
Systox	1.0	7-20	280	1200	42.5
Systox	.5	7-20, 8-1	85	750	58.5
Systox	.5	7-20	260	1400	41.5
Check			870	1700	26.5

[1] Emulsifiable concentrates, schradan 45 per cent and Systox 32 per cent.
[2] Turnip greens and globes per 18 feet of row space harvested on September 14.

EXPERIMENTS ON EGGPLANTS.—Eggplants serve as an excellent host plant for the two-spotted mite, *Tetranychus bimaculatus* Harvey, and such aphid species as *Mysus persicae* (Sulzer) and *Illinioa solanifolii* (Ashmead). For this reason eggplants have been used in several experiments involving systemic materials.

Table 2 shows the comparative performance of Systox, schradan, malathon and parathion treatments applied to mature eggplants heavily infested with the above mentioned pests. The materials were applied only once (September 19) and counts were made on the second and fifth days after spraying to determine the per cent kill. Pepper plants heavily infested with the green peach aphid, *Mysus persicae* (Sulzer), growing alongside the eggplant rows also were treated with the same materials. The degree of aphid kill obtained on these plants closely paralleled that observed on the eggplants.

In a second experiment starting on July 10, young eggplants were sprayed three times at 10-day intervals with different concentrations of schradan and

Table 2.—Mortality of aphids and mites on mature eggplants following insecticide application.

Materials[1]	Pints per 100 Gals.	Aphids Dead Second Day	Mites Dead Second Day	Mites Dead Fifth Day
Systox	1.5	100%	99.2%	99.9%
Systox	1.0	100	99.2	99.2
Parathion	1.0	100	96.1	99.4
Systox	0.5	100	96.0	98.9
Systox	0.25	100	91.5	98.0
Malathon	1.0	100	89.8	93.9
Schradan	1.0	98	67.3	93.0
Schradan	1.5	98	65.6	86.4

[1] Emulsifiable concentrates, Systox 32 per cent, parathion 25 per cent, malathon 50 per cent and schradan 45 per cent.

Systox. The data show that vigorously growing eggplants lose their toxicity quite rapidly. However, plants treated with the concentrations schradan 4–100 and Systox 1–100 gave 80 to 90 per cent aphid control 24 days after the last spray application and 40 to 60 per cent mite control 2 months after the last spraying.

A third experiment was set up for the purpose of comparing residual toxicity of similar concentrations of schradan and Systox with each other and relating these to a standard, parathion. The sprays were applied to mature eggplants late in the season after mite and aphid populations had become established on the plants. Many untreated plots were left throughout the experimental planting in order that reinfestation might occur on systemic-treated plants as soon as they became less toxic to aphids and mites. Figure 1 shows the relative mite control obtained in this experiment. Aphid control on these plots followed the same general pattern as for mites.

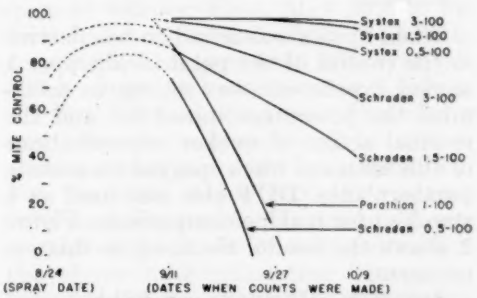

FIG. 1.—Control of the two-spotted mite on mature eggplants. Broken lines show assumed control based on data given in table 2. Solid lines show mite control as determined by population counts. Plants treated with schradan 0.5–100 showed higher mite populations than did untreated plants on 9/27.

When mite control is used as the criterion for determining the amount of schradan or Systox remaining in the plants, the results of this experiment are found to be in direct contrast to those secured in the turnip experiment; whereas schradan showed longer residual action in fast growing turnips. Systox showed better residual action in mature eggplants.

In a fourth experiment eggplants were sprayed at 10-day intervals throughout the growing season using 1.5–100 concentrations of both schradan and Systox. On October 12, 52 days after the sixth and last spray application, Systox was found to be giving 95 per cent mite control while schradan gave only 33 per cent.

EXPERIMENTS ON POTATOES.—Data obtained in one experiment where systemics were used in the control of the potato leafhopper, *empoasca fabae* Harris, are summarized in table 3. Systox was quite effective against the nymphs while little or no control of this pest was obtained with schradan. In this experiment, on nearly mature potato plants, both Systox and schradan were used in two concentrations and were applied only once.

Table 3.—Degree of leafhopper control obtained when one application of systemic materials was made on July 25 to nearly mature potato plants.

MATERIALS[1]	PINTS PER 100 GALS.	AVERAGE NYMPHS PER LEAFLET 7–26	8–1	8–10	8–16	AVERAGE CONTROL
Schradan	2–100	3.1	2.0	3.6	[2]	0 0%
Schradan	6–100	2 6	1.6	3.4	[2]	4.8
Systox	1–100	0.2	0.1	0.1	0.0	94.4
Systox	2–100	0.0	0.0	0.1	0.0	98.8
Check (Untreated)		3.0	1.0	4.0	[2]	0.0

[1] Emulsifiable concentrates, schradan 45 per cent and Systox 32 per cent.
[2] Plants dead.

When Systox was found to be effective in the control of the potato leafhopper a second experiment was set up to determine the percentage initial kill and the residual action of weaker concentrations of this material when sprayed on mature potato plants. DDT also was used as a standard for making comparisons. Figure 2 shows the results obtained in this experiment.

SYSTEMIC RESIDUES.—Schradan and Systox both are highly toxic to warm-blooded animals and for this reason a very important matter concerned with their use on vegetable crops is the residue problem. During the 1951 season a total of 36 samples representing a wide variety of vegetable crops were submitted by the authors for residue analyses. In most cases residue results for both schradan and Systox were so variable that no definite conclusions could be drawn. Some samples showed higher residues remaining in the edible vegetable portion for schradan than for Systox when similar concentrations were compared. In others the reverse was observed.

In view of the fact that Systox has shown good control of the potato leafhopper it should be mentioned that three samples of potato tubers taken from Systox treated plots were included in the submitted samples. The plots were treated with varying concentrations and with

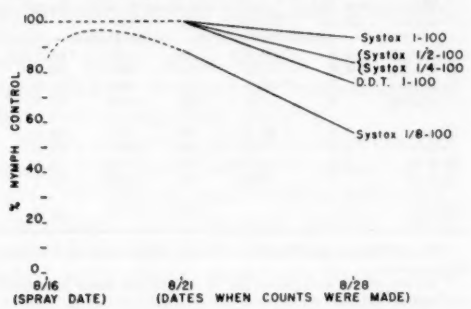

FIG. 2.—Control of potato leafhopper nymphs on mature potato plants. Broken lines show assumed control while solid lines show control determined by population counts.

varying numbers of applications of Systox and in no case was the residue higher than 0.1 p.p.m.

SUMMARY.—Field experiments were conducted during the 1951 season in which schradan and Systox, applied as foliage sprays, were compared with each other and with other organic insecticides in the control of certain vegetable pests. Systox was found to give good initial kill of the potato leafhopper, *empoasca fabae* Harris, in concentrations as low as .25 pints per 100 gallons. Schradan proved ineffective against this insect. Both schradan and Systox gave good control of the two-spotted mite, *Tetranychus bimaculatus* Harvey, and all aphid species encountered, namely *Rhopalosiphum pseudobrassicae* (Davis), *Myzus persicae* (Sulz.), and *Illinoia solanifolii* (Ashm.). Residual action of both systemics is dependent upon the amount of active ingredient applied to the plant. In vigorously growing tur-

nips, Systox gave better initial aphid kill in low concentrations than schradan whereas schradan gave longer residual action for all concentrations tested than did Systox. Systox, however, gave better residual action in mature eggplants when comparable amounts of schradan and Systox were used. Residue analyses of various vegetable samples have shown conflicting results and no general comparisons can be made between schradan and Systox.

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Woolly Apple Aphid in Codling Moth and Mite Control Spray Plots[1]

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During the past few years many reports on codling moth control have noted with alarm the increased incidence of woolly apple aphid *Eriosoma lanigerum* (Hausm) in those orchards sprayed with DDT. This increase has been in most instances attributed to the killing of the woolly aphid parasite *Aphelinus mali* (Hald:)

The following data on the incidence of the woolly apple aphid are taken from our experimental orchard spray tests of 1949 and 1950, which were conducted at Paonia primarily as studies of codling moth and mite control.

METHODS AND MATERIALS.—The 1949 experimental test included eight treatments replicated 4 times in randomized plots. Each replicated consisted of three or more trees of the Delicious variety in tandem in tree rows fifty feet apart. Four spray applications were made. A record was taken of the number of woolly apple aphid infested nodes on 10 water sprouts selected at random from the center or count tree of each replicate. The sprouts were of approximately the same length as evidence by the total number of nodes examined.

During 1950 each treatment was replicated five times on plots of two trees each of the variety Jonathan. Ten schedules of miticides were used in combination with DDT (50 per cent wettable powder at the rate of 1.5 pounds to each 100 gallons of spray solution. Sprays were applied with a conventional type of sprayer with a four nozzle spray broom at 600 pounds of pressure.

All plots received five applications, the timing being based largely on codling moth activity. A cold period the first week of June 1950 prolonged the emergence of the first brood moths. Therefore the third application was a "between brood" spray. All acaricides were omitted from this application. Spraying dates were as follows: First, May 29, 30, 31; second, June 12; third, June 28; fourth, July 24; fifth, August 9–10. The acaricide 88R was used in treatment No. 3 only in the first two applications. The clover mite, *Bryobia pratensis* Gar., became so abundant that parathion was substituted. For the same reason DN 111 replaced EPN in treatment 2. Treatment 10 was started as the check for mite control but the clover mite infestation became so heavy sulfur was added in the fourth and fifth applications to save the foliage.

[1] Scientific Journal Series Paper No. 383 Colorado Agricultural Experiment Station.

Table 1.—The means of the number of apple sprout nodes examined and those found infested with woolly apple aphids under eight treatments which were applied primarily for codling moth and mite control. Paonia, Colo. 1949.

Treatments	Means Nodes Examined	Mean Infested Nodes	Efficiency Rank
1. DDT (50%) 1.5 lbs.; wettable micronized sulfur 8 lbs. (4 lbs. in 4th application)	236.50	5.75	2
2. Parathion (25%) 1.5 lbs.	232.50	0.75	1
3. Methoxychlor (50%) 2 lbs.; parathion (25%) 1 lb.	235.00	5.75	2
4. Methoxychlor (50%) 3 lbs.; DN 111[1] 1.5 lbs. first application, 0.75 lbs. remaining applications	213.75	88.25	7
5. DDT 1 lb.; parathion (25%) 1 lb.	222.50	6.50	4
6. DDT 1.5 lbs.; DN 111[1] as in No. 4	214.00	36.50	6
7. DDT 1.5 lbs.; C-854[2] 1 lb.	222.50	90.50	8
8. DDT 1.5 lbs.; TM-1[3] 1 lb.	190.50	28.00	5
Total	1767.25	262.00	
Diff. Reg. for Sig. 5% point		46.61	
Diff. Reg. for Sig. 1% point		63.57	

[1] Dinitro-o-cyclohexylphenol, dicyclohexylamine salt. 20%. Dow Chemical Co.
[2] P-chlorobenzene sulfonate (50% W.P.). Dow Chemical Co.
[3] TM-1; Dinitro-capryl phenyl crotonate. Rohm and Haas.[3]

Table 2.—Readings of the degree of infestation from the woolly apple aphids under 10 treatments which were applied primarily for codling moth and mite control. Paonia, Colo. 1950.

Treatments, Amounts per 100 Gals. Water	Control Readings		
	Total	Mean	Rank
1. DDT 15 lbs.; DN 111[1] 1 lb. 1st application 0.75 lb., 2nd, 4th & 5th applications	16.5	3.3	6
2. DDT 1.5 lbs.; EPN 0.5 1st and 2nd applications, DN 111 0.75 lb. 4th and 5th	18.5	3.7	8
3. DDT 1.5 lbs.; 88R[2] 1 lb. 1st and 2nd applications, Parathion (25%) 0.75 lb. 4th and 5th	6.5	1.3	2
4. DDT 1.5 lbs.; C-1006[3] 1 lb. 1st, 2nd, 4th and 5th applications	19.0	3.8	9
5. DDT 1.5 lbs.; wettable sulfur 8 lbs. 1st and 2nd and 6 lbs. 4th and 5th	5.5	1.1	1
6. DDT 1.5 lbs.; sulfur[4] 8 lbs. 1st and 2nd and 6 lbs. 4th and 5th	8.0	1.6	4
7. DDT 1.5 lbs.; Toxaphene (40%) 0.75 lb. 1st and 2nd, DMC (25%)[5] 1 pint 4th and 5th	20.0	4.0	10
8. DDT 1.5 lbs.; TM-1 (25%)[6] 1 lb. 1st; 2nd, 4th and 5th	18.0	3.6	7
9. DDT 1.5 lbs.; Parathion (25%) 0.75 lb. 1st, 2nd, 4th and 5th	7.5	1.5	3
10. DDT 1.5 lb.; wettable sulfur 6 lbs. 4th and 5th	12.0	2.4	5
Diff. Reg. for Sig. 5% point		1.116	
Diff. Reg. for Sig. 1% point		1.497	

* 1=0 infested twigs readily visible from base of tree.
2=1 to 3 infested twigs readily visible from base of tree.
3=4 to 6 infested twigs readily visible from base of tree.
4=7 to 10 infested twigs readily visible from base of tree.
5=11 or more infested twigs readily visible from base of tree.
[1] Dinitro-o-cyclohexylphenol dicyclohexylamine salt, 20%. Dow Chemical Co.
[2] Aryl alkyl sulfite. Naugatuck Chemical Division of the U. S. Rubber Co.
[3] p-chlorophenyl-p-chlorobenzene-sulfonate (50% W.P.) Dow Chemical Co.
[4] Fused bentonite sulfur. Niagara Sprayer and Chem. Div., Food Machinery Corp.
[5] Di(p-chlorophenyl) methyl carbinol (25% D.M.C.) Sherwin Williams Co.
[6] Dinitro-capryl phenyl crotonate. Rohm and Haas Co.

RESULTS.—During 1949 effective and not significantly different woolly apple aphid control was obtained with treatments 2, 3, and 5 wherein parathion was used alone or in combination with other materials (Table 1). The DDT-wettable sulfur combination (treatment 1) was equally effective. DN 111 in conjunction with methoxychlor (treatment 4) permitted a greater build-up of the woolly apple aphid than did the combination of DN 111 and DDT (treatment 6). C-854 and DDT (treatment 7) permitted a heavy build-up. The infestations under

treatments 4 and 7 were of definite economic importance. The unexpected results from the use of the DDT-sulfur combination were also apparent in the commercial orchards of the district wherever thorough applications had been made. This is an important development under Colorado conditions, as it affords excellent control of powdery mildew, green aphids, brown mites and codling moth, at a low cost. There seemed to be no phytotoxic effects from the use of the DDT-sulfur combination even though high maximum temperatures prevailed a number of times during mid-season. This DDT-sulfur combination has been incorporated in our experimental plots for a number of seasons. However, this was the first season we were able to gather mathematical evidence pertaining to the control of the woolly apple aphid. The two materials have always shown excellent compatability.

Effective supression of the woolly apple aphid in the 1950 tests came from the use of schedules 3, 5, 6 and 9, in which parathion, wettable sulfur or Kolofog sulfur was used with DDT. There are no significant differences in this group. All four of these first ranking schedules show a highly significant effectiveness over the treatments in which DN 111, Karathane, EPN, C 1006, toxaphene and Dimite were used.

The sulfur-DDT schedules were as effective as the parathion and DDT. Wettable sulfur and another form[1] sulfur were equally effective when combined with DDT. Wettable sulfur used in only the last two applications gave definite woolly aphid control but was less effective than where used in four applications. None of the schedules used showed economic phytotoxic effects. The two sulfurs and parathion, when used with DDT, did not decrease codling moth control.

DISCUSSION.—The combinations of DDT and sulfur and DDT and parathion gave highly significant controls of the woolly apple aphid in the experimental plots of both 1949 and 1950. The DDT-wettable sulphur combination was again effectively demonstrated through grower experience during the season of 1951. The combination was recommended to a number of growers who had reported increasing difficulty in the control of the woolly apple aphid even though they had been using one or two summer sprays of such materials as nicotine sulphate or parathion. They reported that such sprays reduced the aphid population for a time but there was a heavy buildup by the end of the season. This has been experienced in our experimental plots a number of times. Inspection of 6 different orchards in 1951 where the DDT-sulphur combination had been used in four cover sprays, showed practically 100 per cent control of the woolly apple aphid. In these same orchards a number of instances were found where the only aphids present were on trees which had been poorly sprayed or missed entirely.

Following a week of excessively high temperature of 90° F. or above, during 1951 there was some evidence of leaf scald. In no instance was this considered of economic importance by the grower and could not be attributed to the sulphur as the same leaf scald or burn could be found on trees which had not received sulphur or sulphur combination spray during the season.

In our 1951 experimental plots at Cedaredge where woolly apple aphid populations were very high at the close of the season of 1950, the DDT-sulphur combination cleaned up the infestation to near the 100 per cent point and there was no evidence of leaf burn.

SUMMARY AND CONCLUSIONS.—The woolly apple aphid as well as the clover mite and the two-spotted mite populations build-up in Colorado orchards sprayed with DDT for codling moth control. In tests of combinations of acaricides with DDT, definite woolly apple aphid control is shown with DDT and sulphur and DDT and parathion. The use of these combinations has not lowered the efficiency of the DDT for codling moth control. The DDT and sulphur combination has come into general use in Western Colorado. It is giving control of the codling moth, the two spotted mite, the clover mite, the green apple aphid, and the woolly apple aphid, while the sulphur is a necessity for powdery mildew control.

[1] Kolofog.

Effect of Early Season Sprays Against Plum Curculio on Peaches

CARL J. WEINMAN[1]

During the past several years, Illinois recommendations for the control of plum curculio on peaches have been shifting toward earlier application of the first spray. Until 1948, for example, growers were told to begin sprays for curculio when the shucks were half-way off. Then in 1949 and 1950, growers were advised to apply the first curculio spray when the shucks first begin to split. In 1951, for the first time, provision for a petal-fall application for curculio was included in the recommendations. This change has been brought about largely through the observations of Mr. S. C. Chandler, associate entomologist, Illinois Natural History Survey, that the first dropped fruit in late spring had the highest percentage of curculio entries (unpublished data). In well-sprayed orchards, the percentage of curculio larvae decreased abruptly in dropped fruit picked up after the first week in June. It appeared, therefore, that spraying for curculio simply was started too late.

It should probably be mentioned that under normal Illinois conditions peaches in unsprayed orchards are nearly 100 per cent infested with curculio and most are on the ground by the end of the first-brood period. The importance of first-brood control is, therefore, readily apparent.

During the season of 1950, a series of tests was run to study the effects of varying the time of application of first-brood sprays for curculio control on peaches. One of the orchards used in this experiment was divided in half and sprayed at the time of 50 per cent bloom to determine the value of dieldrin against catfacing insects. The north half of this orchard, next to a large, poorly sprayed, and heavily infested block of trees not included in the experiment, was sprayed once (at 50 per cent bloom) with 8% actual dieldrin per 100 gallons of spray. Sulfur alone was applied to this plot at full bloom. The south half of the orchard was sprayed with 1 lb. actual DDT plus sulfur twice—at 50 per cent and at full bloom.

Examination of drops during the growing season and of picked fruit at harvest showed 2.0 per cent catfaced drops and 3.0 catfaced fruit at harvest, with 2.7 per cent of the total crop from 10 record trees catfaced in the dieldrin plot. The plot which was sprayed twice during bloom with DDT had 7.3 per cent catfaced drops, 9.6 per cent catfaced picks, with 8.8 per cent of the total crop (from 10 trees) catfaced. A further examination of the data revealed that at the end of the first-brood period, fruit in the dieldrin plot showed 43.6 total curculio injuries per 100 fruit, whereas there were 76.0 such injuries per 100 fruit in the half sprayed twice during bloom with DDT. Moreover, 10 trees in each plot jarred at six times during the first-brood period produced 97 curculios in the dieldrin plot and 218 curculios in the block sprayed with DDT.

Peaches from this orchard were harvested on September 17. At that time, the difference between plots was still apparent. Among all the fruits still on the 10 record trees in each plot at harvest, there were 48.1 stings and 53.1 entries per 100 fruits in the plot sprayed with dieldrin in bloom and 60.2 stings and 78.3 entries per 100 fruit in the DDT-sprayed half. Catfacing among the picked fruit at harvest amounted to 3.0 per cent in the dieldrin block and to 9.6 per cent in the DDT plot.

Inasmuch as the only constant difference between the two halves of this experimental orchard was in the bloom sprays applied, dieldrin having been used over the whole orchard in sprays starting with the shuck-split application, there was good reason to suspect that the early spray of a material known to be effective against plum curculio was much more important in control than had been suspected. The persistence of the difference in curculio injury between the two plots even to harvest was the more surprising because no sprays of any kind were applied in this orchard after May 29. Under Illinois conditions, sprays for curculio are

[1] Entomologist, Illinois Natural History Survey. The author gratefully acknowledges the advice and help in planning the experiment of George C. Decker, entomologist and head, Illinois Natural History Survey and Illinois Agriculture Experiment Station. Jeane C. Warner, research assistant, and others assisted in the field work and in the statistical analysis of the data.

usually continued until two or three weeks before harvest. Furthermore, the proximity of the large, poorly sprayed orchard to the dieldrin plot gave additional credit to the hypothesis that beginning curculio sprays in the bloom can show a season-long advantage over starting the control with the shuck-split application. The high incidence of plum curculio in this orchard and the scarcity of sucking insects in jarring collections suggested that the reduction in catfacing was probably also the result of improved control of curculio.

Few Illinois growers regularly apply any spray to peaches at petal fall. In general, therefore, the 1951 recommendation that a petal-fall spray of chlordane be applied had the effect of increasing the season total applications by one. In all except the most northern peach growing area of Illinois, however, growers do apply one or more sprays during bloom for the control of blossom blight. DDT has been included in these bloom sprays for the control of catfacing insects other than curculio (Chandler 1948). Since the 1950 experiment had indicated that the first curculio spray might be applied as early as the time of 50 per cent bloom with good results, and since most growers apply a spray at full bloom anyway, the possibility of using an insecticide other than DDT for the control of both curculio and sucking insects at full bloom was the subject of the investigations here reported.

PLAN OF EXPERIMENT.—As the object of the 1951 experiments was to determine the advantages or disadvantages in the application of a spray for curculio control at bloom time, plots of the standard schedule (DDT in bloom, followed by chlordane or parathion in the petal-fall or shuck-split application) were paired against plots in which dieldrin, chlordane, or parathion was used in the bloom and next spray (petal-fall or shuck-split, depending on the orchard practice). Thereafter, both plots of each pair were sprayed alike for the rest of the season. In most orchards, each plot was half an orchard in size, but some of the larger orchards were divided into three or four plots. Twenty orchards, representing 50 plots, were used in the entire study, and these were distributed from Villa Ridge, in the extreme southern tip of Illinois, to Lima, 30 miles north of Quincy. Most of the tests were in blocks of Elbertas, but Red Haven, Golden Jubilee, Georgia Belle, Cling, Hale Haven, and Gage Elberta were used for some pairs of plots.

Most of the test plots were sprayed with dieldrin at 4 ounces (actual) per 100 gallons in the bloom and petal-fall or shuck-split applications, since this compound had given such excellent results in our 1950 experiments and because it has been shown to be highly effective against curculio, with a long residual activity (Chandler 1950; Snapp 1951; Wylie 1951). Dieldrin at 8 ounces in the bloom spray only, followed by the standard schedule, and parathion or chlordane in the bloom and next application were included in a few of the test plots.

RECORDS.—Jarring records were taken on trees in the five rows at the edge of the various plots from one to several times between April 18 and May 30, which was roughly between petal-fall and the time of the second-cover spray in the various orchards.

After the fruit had set, five trees near the center of each plot were marked for records. As nearly as possible, records were taken on every fruit on each marked tree in each plot. Drops were collected at irregular intervals from May 23 until harvest, and every drop was examined. At harvest, every fruit still on the tree was examined, and those showing curculio or suspected curculio damage were removed and further examined by cutting to determine whether the blemishes represented entries or stings or damage from some other insect. In three of the orchards, trees were too tall to permit examination of the highest fruit, even from a 10-foot ladder. In these plots the peaches which could not be reached were counted so that we still would have the number of total fruit per tree.

Near the end of the first-brood period, 50 peaches from each of 10 trees in each plot were examined for curculio damage. Since these fruit were not cut to determine whether a blemish was a sting or an entry, all injuries were recorded as stings. Counts of both the per cent of fruit stung and the total stings per 100 fruit were made. In all other counts, however, stings were recorded only from fruit which did not also have an entry.

RESULTS.—The results of these experiments appear in tables 1 to 6. In order to study the effects of the different bloom

sprays also on insects other than curculio, the data are arranged in two groups in each table. In one are summarized the records from orchards having a moderate to heavy infestation of curculio, and in the other are the average records from orchards which experienced only light curculio attack in 1951. Not all of the 50 plots are included in these summaries, because it was impossible to get complete records on a few orchards—mostly because a number of plots were abandoned before harvest when severe injury from the previous extreme winter caused defoliation of the trees or premature drop of fruit.

The statistical significance of the results was tested by "Student's" t-test for paired values. The occurrence of obviously anomalous results led to the development and use of a method which takes account of the fact that the data reported (e.g. per cent of damaged fruit) result indirectly, the direct effect of the treatment being on the number of living insects.[1]

In table 1 are recorded the average numbers of plum curculios and sucking insects (mostly stink bugs) jarred during the early part of the season (between April 18 and May 30 in the various plots). Most of the jarrings were made after the shuck-split application, by which time all orchards had been sprayed for curculio. The statistically highly significant difference in numbers of curculio adults between those plots sprayed for curculio in bloom and those sprayed with DDT emphasizes the persistence of low numbers of adults in the test plots throughout the jarring period.

Most peaches infested with curculio larvae drop off the tree before the larvae are mature. The incidence of curculio infestation in dropped fruit is, therefore, always higher than in the fruit on the tree. The examination of every dropped fruit from each of five record trees in each plot throughout the entire season gives a reliable index of the abundance of curculio at different times between bloom and harvest. Table 2 is a summary of the season's records on dropped fruit. These show a highly significant difference in curculio damage (except catfacing), in favor of the curculio bloom spray in orchards having a moderate to heavy infestation. Among the plots having only a light infestation, differences in stings and entries are significant, but only the difference in per cent entries is highly significant.

Since both pairs of plots in each orchard were sprayed alike except for the first one or two applications, it might be anticipated that the earliest drops would show the greatest difference in control between the test and standard treatments. That this is actually true is shown by the data in table 3. Orchards in which curculio was a problem had highly significant differences in all categories except oriental infestation. As early as May 23, grown larvae were found in dropped peaches no larger than a man's thumbnail—peaches which showed no development beyond that attained at shuck-fall time. In other years we have considered such peaches to have failed to develop because of "poor set" or "weak buds," and they were not included in our drop examinations. These tiny fruit were almost 100 per cent infested in the standard blocks of some orchards. Since it is considered to take about a month for larvae to develop to maturity at that time of the year, the eggs must have been laid certainly earlier than the shuck-split stage.

The data on per cent of curculio damaged fruit and total injuries per 100 fruit from peaches still on the tree at the end of the first-brood period appear in table 4. Since it can be assumed that most of the earliest entered fruit had dropped by this time and that most of the stung peaches were attacked later than the shuck-split stage, it is surprising that there is so great a difference between standard and test blocks so late in the season. These results again give reason to suspect that populations in the test plots never built up to the level of those which did not get a curculio spray in bloom. Such a conclusion implies that adult curculios do not move around much within an orchard when there is an abundance of food, but this implication is contrary to the generally accepted opinion.

Table 5 summarizes the results from examination of fruit still on the record trees at harvest. Even though the two members of each pair of plots were sprayed alike throughout the season after the shuck-split application, there still

[1] This modification was developed by H. W. Norton, professor of agricultural statistics, University of Illinois, and thanks are due him for help in the more accurate evaluation of the experimental results.

Table 1.—Jarring records—Early first-brood period (42 paired plots).

	Ave. Number of Insects Jarred from 5 Trees per Plot	
	Curculio	Sucking Insects
Curculio spray in bloom	8.0[1]	4.8
No curculio spray in bloom	27.9	6.6

[1] Difference highly significant.

is a highly significant difference between treatments in entries, carfaced fruit, and per cent of clean fruit in those orchards having moderate to heavy curculio infestations.

In table 6 are the data for the total crop (drops and picks), averages of all the fruit on each of the 5 record trees in each plot. Again, in the moderately to heavily infested orchards, there are significantly lower percentages of fruit stung, entered, and catfaced in the plots in which a curculio spray was applied during bloom. Moreover, there are 10.7 per cent more clean fruit in these plots, and 7.0 per cent more fruit ("per cent picks") still on the trees at harvest time.

Although, in table 6, none of the differences between treatments in orchards having only a light infestation of curculio is significant, there is slight evidence in the results listed in tables 2, 3, and 6 that the DDT used in the bloom period is somewhat more effective than the other insecticides against catfacing insects other than curculio.

DISCUSSION.—In two orchards, it was possible to make a direct comparison in results between the use of dieldrin and parathion during the bloom period. In both orchards, dieldrin (4 ounces actual) was superior to parathion (0.3 lb.) in all categories. Chlordane was used (at 1 lb.) in the bloom in two orchards, and it too was less effective than dieldrin. Chandler (1950) has shown that five applications of dieldrin throughout the season were more effective than eight sprays of chlordane, parathion, lead arsenate, BHC, aldrin, EPN, or dilan in the control of plum curculio. Snapp 1952, reports that only dieldrin among 9 materials tested gave adequate control of curculio under conditions of heavy infestation.

The period between bloom and shuck-split may be as short as a week or it may be 3 weeks or longer, depending on the weather. It is important, therefore, that the insecticide used during bloom for the control of curculio have a long residual effectiveness. Among the organic insecticides now in use commercially or experimentally on peaches to control curculio, dieldrin has the longest residual effect. For these several reasons, it seems that dieldrin offers the greatest promise for use in early season sprays to combat plum curculio.

Chemical analyses of leaves and fruits from some of the plots included in these experiments showed no residues of dieldrin at harvest. In another orchard, not included in these tests, fruit from a plot

Table 2.—Total drops. Ave. from 5 trees per plot.

	Orchards with Mod.-Heavy Curculio (28 Paired Plots)					Orchards with Light Curculio (16 Paired Plots)				
	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean
Curculio spray in bloom	5.7†	15.6†	12.0	12.5	58.8†	6.6*	0.4†	2.5	4.9	86.2
No curculio spray	7.9	27.3	10.0	12.9	47.9	9.8	2.5	1.4	3.9	82.7

* Difference significant.
† Difference highly significant.

Table 3.—First pick-up of dropped fruit—Early first-brood period. Ave. from 5 trees in each plot.

	Orchards with Mod.-Heavy Curculio (28 Paired Plots)						Orchards with Light Curculio (18 Paired Plots					
	Per Cent of Total Crop	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean	Per Cent of Total Crop	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean
Curculio spray in bloom	13.7†	3.8†	14.3†	3.8	10.0†	69.9†	7.8	1.9	0.4†	0.04	8.1	89.9
No curculio spray in bloom	22.0	6.3	34.5	2.6	14.7	49.5	6.0	2.6	1.6	0.0	5.4	90.5

† Difference highly significant.

Table 4.—Total stings and entries near end of first-brood period. 50 fruit examined from each of 10 trees in each plot.

	Orchards with Mod.-Heavy Curculio (24 Paired Plots)		Orchards with Light Curculio (18 Paired Plots)	
	Per Cent Stung	Stings per 100 Fruit	Per Cent Stung	Stings per 100 Fruit
Curculio spray in bloom	17.7†	24.0†	6.3	8.7
No curculio spray in bloom	27.8	43.8	7.1	9.4

† Difference highly significant.

Table 5.—Total picked fruit. Ave. from 5 trees per plot.

	Orchards with Mod.-Heavy Curculio (28 Paired Plots)					Orchards with Light Curculio (18 Paired Plots)				
	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean
Curculio spray in bloom	16.0*	2.5†	13.1	5.9†	65.6†	4.6	0.14	1.2	2.2	92.4*
No curculio spray in bloom	19.2	8.0	14.7	12.9	53.3	3.2	0.22	0.6	2.1	94.2

* Difference significant.
† Difference highly significant.

sprayed 4 times with dieldrin (at 4 oz. actual per 100 gallons) between Arpil 27, and May 14 showed 2.7 p.p.m. of dieldrin 10 days (May 24) after the final application. On June 15, 0.4 p.p.m. of dieldrin remained on the fruit in this plot, but on June 22 and thereafter until harvest (August 16) no dieldrin could be detected on the fruit or leaves (Table 7).

Analyses of residues from Elberta peaches sprayed with dieldrin (4 oz.) 5 times beginning May 12 and ending July 25 in 1950 showed 0.15 p.p.m. on field-sampled fruit at harvest, August 17. On the same date, samples of fruit taken after they had been run over grading equipment had 0.11 p.p.m. of dieldrin residue.[1] The commercial use of dieldrin on peaches as late as July, however, is not contemplated, but it does seem that this insecticide can be used without creating a residue hazard if applications are limited to the first-brood period (end of June or earlier throughout most of the peach-producing areas of Illinois). Even if dieldrin were much more persistent than it is, its use in only the early season sprays, as reported in these present investigations, would not result in a harvest residue, since the factor of growth dilution alone would reduce the spray material present at shuck-split time or even at first cover to a very low level. The ratio of peach size at harvest to size at the time of the first-cover application (10 days after shuck-split) is about 20:1.

Summary and conclusions.—Fifty paired plots in 20 orchards in Illinois were used for these experiments, in which the standard schedule (DDT in bloom followed by chlordane or parathion in the next application) was compared with one in which a material effective against curculio (dieldrin, chlordane, or parathion) was used in both the bloom and the second spray.

Curculio control, judged by several cri-

[1] All chemical analyses here reported were made by James M. Bann, special research assistant, Illinois Natural History Survey.

Table 6.—Summary, total crop. Ave. from 5 trees per plot.

	Orchards with Mod.-Heavy Curculio (28 Paired Plots)						Orchards with Light Curculio (18 Paired Plots)					
	Per Cent Picks	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean	Per Cent Picks	Per Cent Stings	Per Cent Entries	Per Cent Oriental	Per Cent Catfaced	Per Cent Clean
Curculio spray in bloom	62.8†	11.4†	8.0†	12.3	8.8†	63.2†	89.8	4.4	0.15	1.2	2.7	92.0
No curculio spray in bloom	55.8	13.7	16.3	11.8	13.0	52.5	90.6	3.6	0.4	0.7	2.1	93.5

† Difference highly significant.

Table 7.—Dieldrin residues on peach (foliage and fruits) p.p.m. at intervals after last treatment, Bartelso, 1951.

	Dates						
	May 24	May 25	May 31	June 7	June 15	June 22	August 16
Plot A							
Days after last spray		1	7	14	22	29	84
Residue- leaves		23.0	12.7	5.95	13.4*	—	0.0
Residue-fruit		5.79	1.98	2.2	3.24*	—	0.0
Plot B							
Days after last expt. spray	10		17	24	32	39	94
Residue-leaves	10.02		4.62	2.31	1.14	0.0	—
Residue-fruit	2.68		1.31	1.38	0.38	0.0	—

* New application of dieldrin.
Harvested August 16, 1951.
Plot A: Five applications of dieldrin, ½ lb. actual—April 27, May 3, May 8, May 14, May 24; parathion, 2 lb.—June 5; dieldrin, ½ lb.—June 13; parathion thereafter.
Plot B: Four applications of dieldrin, ½ lb. actual—April 27, May 3, May 8, May 14; parathion thereafter.

teria, was significantly better in those plots receiving a curculio spray in bloom than in those sprayed with DDT in bloom, where plum curculio infestations were moderate to heavy.

The per cent of catfaced fruit was significantly lower where a curculio bloom spray was applied except in orchards having only light infestations of curculio.

The per cent of the total crop remaining on the tree at harvest was significantly greater in those plots sprayed with dieldrin, chlordane, or parathion in bloom, in orchards having moderate to heavy populations of curculio.

Among the materials tested, dieldrin offers the greatest promise in early season sprays for the control of curculio.

No residues of dieldrin could be found chemically at harvest on leaves or fruit from plots sprayed with dieldrin in the bloom and shuck-split applications. No residue of dieldrin remained after June 22 on fruit sprayed 4 times with dieldrin (4 oz. per 100 gallons) between April 27 and May 14.

The known rate of loss of dieldrin, together with the factor of growth dilution, precludes the possibility of perceptible residues of dieldrin at harvest on fruit sprayed with this compound not later than the first-cover application.

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Influence of Population Density on *Tetranychus multisetis*[1]

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During the course of a biological study on a spider mite, several effects of population density were noted. The species studied was initially identified as *Tetranychus bimaculatus* Harvey by E. A. McGregor. Since the time of the above studies, it was learned that McGregor has described this mite as a new species, *Tetranychus multisetis*. The mite is very closely related to the two-spotted mite both in habits and morphology.

The mites were reared on ripe banana squash fruit, and barriers of petroleum jelly were used to prevent them from leaving the host. The relative populations of mites were observed by rotating the squashes under a binocular microscope and counting the mites that fell within a 4 mm. wide field of vision. It was necessary to sample equally both upper and lower surfaces of the squashes, since the mites increase on the lower surfaces before they do on the upper. In all cases at least five per cent of the total area of the squash was examined. This was accomplished by counting the mites in about eight bands around each squash. The location of these bands was marked on each squash and the same areas were sampled throughout the experiment.

A population was started by placing 50 adult female mites on the squash surface. A period of about 45 days was required for the mite population to reach its maximum density. Once the peak population was reached there was an abrupt decline in the numbers of mites. By the time a colony was 85 days old the population was very low, but a few individuals could still be found in a colony after 5 months. This rapid decline of the population was due to the fact that the mites fed on the surface cells of the squash, and once an area had been heavily populated it would no longer support them.

INFLUENCE OF POPULATION DENSITY ON THE NUMBER OF EGGS.—The population trends on eight squashes were determined by observations made at ten day intervals. The total number of females and eggs was recorded and the number of eggs per female calculated. A summary of the results is given in table 1. The figures obtained prior to 25 days and after 75 days are omitted because the counts were so low that the ratio of eggs to females was of questionable value. At the end of 25 days the average number of eggs per female was 7.04. Ten days later the number of females had about doubled and the number of eggs per female had increased to 8.44. The population showed spectacular increases in the period just preceding the 45 day mark. Both the number of females and the number of eggs increased, but the average number of eggs per female dropped to 6.23. Ten days later this figure was only 2.99, by the 65 day period it reached 2.27, and at the end of the experiment it had decreased to 1.46.

Table 1.—Number of eggs and adult female mites, with the average number of eggs per female, obtained from samples taken at 10-day intervals on eight banana squashes.

DAYS FROM START OF COLONY	NUMBER OF FEMALES	NUMBER OF EGGS	AVERAGE EGGS PER FEMALE
25	27	190	7.04
35	48	405	8.44
45	252	1569	6.23
55	146	437	2.99
65	97	220	2.27
75	37	54	1.46

From the foregoing information it is seen that the total number of eggs continued to increase until the peak adult population was reached, but the average number of eggs present per female had started to decrease some time before this peak was reached. This indicates that the scarcity of food due to crowding and over-feeding was beginning to have an effect on the oviposition rate before the impact on the total numbers of mites became apparent. This type of behavior due to crowding has been recorded by a number of workers in various zoological fields, and examples have been shown in insects by Park (1936) who worked with

[1] From work done at the University of California, Berkeley.

Tribolium, and by Pearl (1939) who studied *Drosophila*.

INFLUENCE OF POPULATION DENSITY ON VIABILITY OF EGGS.—Nonviable eggs could be recognized within about 24 hours from the time of laying by their slight shrinkage and lusterless color. By the end of about 5 days the nonviable eggs were badly shrunken and dried. In making counts on nonviable eggs, those more than 5 days old were not counted. This made possible the comparison of eggs of approximately the same age, inasmuch as the viable eggs normally hatch in 5 to 7 days at the temperature used in the experiments.

The results of the experiments on egg viability are shown in table 2. Two squashes were used and the sampled areas covered a total of 173 out of a possible 1883 square centimeters. During the period from the time the colony was 25 days old until it reached its peak 20 days later, the percentage of nonviable eggs remained fairly constant at about 3.5 per cent. From then on, however, there was a fairly rapid rise in the percentage of nonviable eggs. By the thirtieth day of observation there were 7.84 per cent nonviable eggs, 10 days later it was up to 18.18 per cent, and by the end of the 50 day period of observation it reached 35.71 per cent. The cause of nonviability was apparently associated with nutrition and due directly to a lack of embryonic development, and not to a lack of fertilization, since viable unfertilized eggs will develop into males.

Table 2.—Egg deposition and percentage of nonviable eggs, taken at 10-day intervals starting at the time the colony was 25 days old, and two banana squashes.

DAYS FROM START OF COLONY	EGGS IN SAMPLES	PER CENT NONVIABLE
25	409	3.42
35	1136	3.52
45	2493	3.33
55	769	7.80
65	110	18.18
75	45	35.56

INFLUENCE OF POPULATION DENSITY ON LONGEVITY.—It seemed probable from observations made that the adult mites had a shorter life span under crowded conditions then where populations were more sparse. No figures were obtained on the life span of individual mites under crowded conditions as no feasible method of marking the mites for this study was available.

Among the young forms, however, there was a decided mortality due to crowding. Mite colonies expand largely at their perimeters. This often results in eggs and immature mites being left stranded in fed-over areas. The young mites are not as active as the mature mites, and many of them die without working their way to the outer edges of the colony. Mortality from this source is particularly high among newly hatched larvae. In one case 263 eggs were counted in the center of a dense expanding colony. One week later 178 dead larvae were found in the same area. In addition to the dead larvae in the center of the colony, there were more dead larvae found near the perimeters that could not be clearly identified with the original eggs. Admittedly this case was an extreme in population numbers and rapid rate of expansion, but it does show that there can be considerable mortality due to expansion.

Table 3.—Number of individuals measured and their average sizes in mm. of mites grown in crowded conditions and those reared in sparse colonies.

STAGE AND SEX	CROWDED POPULATIONS			SPARSE POPULATIONS		
		Average			Average	
	Number	Length in mm.	Width in mm.	Number	Length in mm.	Width in mm.
Eggs	20	0.14	0.14	18	0.14	0.14
Quiescent larvae	13	0.21	0.16	6	0.21	0.16
Quiescent protonymphs	11	0.27	0.17	5	0.26	0.17
Quiescent male deutonymphs	10	0.30	0.18	5	0.30	0.18
Quiescent female deutonymphs	6	0.38	0.23	6	0.37	0.23
Adult males	19	0.33	0.18	13	0.33	0.18
Adult females	15	0.43	0.27	12	0.43	0.27

INFLUENCE OF POPULATION DENSITY ON SIZE.—Extensive measurements were made of individuals at various stages of the population development, but no significant differences in length or width were found between mites raised under crowded conditions and those raised in sparsely populated areas. A summary of the measurements is given in table 3.

INFLUENCE OF POPULATION DENSITY ON SEX RATIO.—It has been assumed in the past that when the population of mites is low, there is much less chance for a male locating a female. Consequently many females will produce males only in the following generation and thus the ratio of males to females increases. This may sometimes be the case in extremely sparse populations, but all females appeared to have been fertilized in the present work. Seventy-five females, picked at random from sparse populations, were isolated. Forty-two of these females were picked from squashes on which the population was so sparse that females were difficult to find. All produced females in the F_1 generation, thus indicating that fertilization had taken place. It is still possible that some of these females had not been fertilized immediately upon maturity, but instead some time later on after the first eggs had been laid but before they were isolated for the experiment.

Two colonies were allowed to run their full course and the sex ratio checked over the entire period. For the first 3 months the sex ratio remained fairly constant, then there was a slight rise in percentage of males during the final two months. The monthly average percentage of males, in chronological order of occurrence were: 23.7, 23.2, 19.9, 31.0 and 29.9. It should be pointed out that the populations were so low during the last two months that the figures do not show a statistically significant change in sex ratio.

INTERACTION OF PREDATORS AND HOST DENSITY.—It is a general belief that concentrated populations of insects are more vulnerable to attacks by predators and parasites than are scattered populations. If this principle holds true for spider mites, the question arises as to why certain species of mites tend to congregate in one area while nearly foliage is almost free from infestation. This can be at least partially explained by the mite webbing. Certain spider mites in concentrated populations accumulate great masses of webbing and live in or under this canopy. The webbing was repeatedly observed to entangle and delay certain predators such as lace wing larvae. In addition the webbing acts as a protective device against disturbing factors such as wind, rain and spray particles. The protection provided by the webbing may be great enough to compensate for much of the adverse effect due to crowding. As a comparison it can be noted that some related mites, such as the European red mite, normally do not live in concentrated colonies, and in turn do not have the masses of webbing.

SUMMARY.—Experiments using a spider mite, *Tetranychus multisetis* McG., raised on the fruit of banana squash show that dense populations resulted in a lower egg production per female and a higher percentage of nonviable eggs, than occurred in a sparse population. The reduced number of eggs per female was noted prior to the highest population peak, but the increase in nonviable eggs was not discernible until after the peak was reached. There was also a definite mortality among the young mites due to crowding. In spite of these adverse effects resulting from dense populations and the fact that concentration in small areas makes a host more vulnerable to attacks by predators, it is believed that the webbing affords enough protection to offset much of the harmful effect of crowding.

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Laboratory and Field Tests with Vaporized Lindane Against Four Species of Roaches

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The roach control problem has been greatly alleviated with the advent of the new organic insecticides. A few years ago pyrethrum and sodium fluoride were widely used in roach control (Laudani & Sweetman 1942), whereas today chlordane and DDT appear most common (Kuitert & Kelsheimer 1950). At present chlordane dusts and sprays are the best means of controlling roaches in most situations. The use of space aerosols, poison baits, traps and fumigation has also been superseded (anon. 1950), although in isolated cases they may be of value.

The development of a new method of application, *i.e.* continuous vaporization of minute amounts of insecticides, induced this research. Commercial vaporizers[2] equipped with dependable temperature regulators were used (Moore & Sweetman 1951, Sweetman & Spear 1952, Spear & Sweetman 1952). A number of commercial devices for vaporization of insecticides are available, which do not permit adequate control of amounts dispersed. Such vaporizers generally give off excessive amounts and are comparable to fumigating equipment. They are considered too hazardous to use for continuous vaporization of toxic substances, where workers continue their normal activities. Devices suitable for continuous vaporization of insecticides should be equipped with reliable controls to permit evolution of insecticides as lindane in amounts of about one gram or less per 15,000 cubic feet per 24 hours.

MATERIALS AND METHODS.—These experiments were conducted in buildings at Amherst, Massachusetts. Four species of roaches, the american roach, *Periplaneta americana* L.; the australian roach, *P. australasiae* P.; the german roach, *Blatella germanica* L.; and the oriental roach, *Blatta orientalis* L., were involved in these tests. Both caged and free roaches were used.

The laboratory roaches were reared on a food mixture of several cereals, powdered skim milk, and powdered yeast. The rearing chambers were 12 by 18 inch glass cylinders resting on slate slabs as bottoms with glass plates as covers. Pieces of 10 by 15 inch cardboard folded to form a V, were placed in the chambers to serve as resting and hiding space for the roaches. Water and food were replenished at least twice weekly. The roaches were raised at a temperature of about 72° F. with the relative humidity ranging from 70 to 90 per cent (Tuma 1942).

For laboratory testing purposes 20 roaches, 10 males and 10 females were placed in fabric cages (Spear 1951) with sufficient food and water. These cages were then placed in sets of three at varying distances, 5, 7, 10, 25, 37, and 50 feet, from the vaporizer. Each set contained a cage of american, australian and german roaches. Lindane was applied from vaporizers at dosages of from 1.6 to 3.5 grams per 20,000 cubic feet per day for periods of 14 to 27 days. The roaches were observed during the exposure and survivors for 2 weeks after the tests. A total of eight tests were conducted in this manner.

Natural infestations of german and oriental roaches only were avaliable. Lindane was applied from vaporizers and as a spray from hand pressure sprayers. A 2 per cent chlordane emulsion was applied as a spray for comparative purposes. Only selected surfaces were treated with the spray applications.

The degree of infestation was determined prior to treatment by averaging a series of 3 or 4 observational counts. At this time all noticeable harborages of the insects were examined. In order to obtain a more accurate measure of the population a trace of pyrethrum dust was used to stimulate the roaches to greater activity.

DISCUSSION.—In the laboratory tests the german, american and australian roaches varied in their susceptibility to vaporized lindane (Table 1). The german roach was the most susceptible while the australian raoch was the most resistant. American and australian females were

[1] Contribution from the Entomological Laboratory of the University of Massachusetts.
[2] Product of American Aerovap Inc., New York, New York.

Table 1.—The mortality of German, American and Australian roaches from vaporized lindane in laboratory tests.

Species	Per Cent Mortality	
	Female	Male
German roach	100.0	92.5
American roach	53.7	91.2
Australian roach	18.7	32.5

noticeably more resistant than the males to this treatment.

The length of exposure had a decided effect on mortality (Table 2). The longer periods of exposure gave correspondingly higher kills. No apparent difference in the rate of mortality between the different dosages was evident. Similarly, the distance of the cages from the vaporizer had no noticeable effect. Mortality from the treatments did not increase during the 14 day period following exposure to the vapor.

About 50 per cent of the german roach population was killed within the first 24 hours after exposure to the lindane vapor. In six of the eight tests all german roaches were dead in 4 days, indicating a relatively high degree of susceptibility.

The results with natural infestations (Table 3) show that chlordane spray was more effective than either lindane spray or vapor applications against german roaches. Two treatments with a 0.3 per cent lindane spray failed to eradicate a

Table 2.—The effect of length of exposure on mortality of German, American and Australian roaches in three laboratory tests with lindane vapor.

Species	Per Cent Mortality		
	14-Day Exposure	20-Day Exposure	27-Day Exposure
German roach	92.5	100.0	100.0
American roach	72.5	57.5	87.5
Austrlian roach	0.0	50.0	52.5

mild infestation of german roaches in a private home. When a 2 per cent chlordane spray was applied the infestation was eradicated quickly. Vaporized lindane eradicated a mild infestation of german roaches in a food storage building but failed to control a moderate infestation in a well-ventilated dining hall basement. Several open windows and two large fans provided a high degree of ventilation in this area of the basement. However, only a small portion of the entire building was treated in the latter instance and roaches could move freely in and out of the treated area. A 2 per cent chlordane spray following the lindane application gave only fair control. This was the only instance in which chlordane failed to eradicate the german roach. The effect of chlordane on oriental roaches was not tested because of the limited number of infestations available. No apparent repellency to either species was observed with chlordane or lindane.

Table 3.—Results of tests with lindane and chlordane against infestations of german and oriental roaches.

Cubic Capacity and Degree of Infestation	Gms. Lindane Vapor. 20,000 Cu. Ft./Day & Days Exposed		Gms. of Insecticide per Spray Application		Results
35,000[4] German-light	2.69	14	—	—	Eradication
8,916[5] German-medium	1.44	56[1]	—	—	Failed[2]
6,881[6] German-light	—	—	Chlordane	—	Control[3]
5,279[6] German-light	—	—	Lindane	7.57	Control
	—	—	Chlordane	56.76	Eradication
	—	—	Lindane	6.06	Failed
	—	—	Lindane	6.06	Control
	—	—	Chlordane	42.57	Eradication
14,440[7] Oriental-medium	0.88	182[3]	—	—	Eradication
15,828 Oriental-heavy	2.23	131	—	—	Eradication

[1] First 39 days operating 14 hrs. per day; last 17 days, 24 hrs. per day.
[2] Partial treatment of building; possible migration from other parts.
[3] Eradication in 51 days; treatment continued as preventive measure.
[4] Food Storage Building.
[5] Dining Hall Basement.
[6] Private Home.
[7] Store Basement.

The lindane vapor applications eradicated the oriental roach from two store basements. A decided advantage of this method over conventional methods (sprays and dusts) was exemplified in these tests. One basement divided into several rooms was virtually filled to capacity with wooden and paper cartons of goods and it would have been very laborious and objectionable to apply a spray or dust under such conditions. It was necessary to move the vaporizer from room to room in order to get distribution of the vapor, since tightly constructed walls existed.

It is quite possible that continuous vaporization of lindane would serve as an effective preventive measure against german and oriental roach infestations.

SUMMARY AND CONCLUSIONS.—The effectiveness of lindane vapor against the american, australian and german roaches under caged conditions was determined at distances up to 50 feet from the source of liberation of the vapor. Vaporization rates varied from 1.6 to 3.5 grams per 20,000 cubic feet per day. The german roach was more susceptible than either the american or australian roach. Female american and australian roaches were noticeably more resistant than the males while there was no significant difference between the susceptibility of male and female german roaches to the concentrations of lindane vapor used. Deaths among the roaches gradually increased during the period of exposure, 27 days. All three species deposited egg cases during the period of exposure.

Since continuous vaporization of lindane at recommended rates of evaporation requires considerable time to overcome german and oriental roach infestations, the value of vaporized lindane against these roaches lies in its use in conjunction with eradication and preventive treatments against other structural pests (Moore & Sweetman 1951, Toczydlowski & Moore 1951, Sweetman & Spear 1952). Chlordane spray or dust treatments are recommended for quick eradication of roaches.

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Effects on Citrus of 2,4-D Used as an Amendment to Oil Sprays[1]

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During the past 25 years oil sprays have become the most widely used means of citrus pest control in California because they have, in general, been the most efficient insecticide available per unit cost. Late summer (August and September) has usually been the most favorable time for applying these sprays to orange and grapefruit trees. At this season navel orange trees do not yet bear mature fruit, and fruit of Valencia orange and grapefruit trees has largely been harvested. Lemon trees are sprayed once or twice a year, as required for pest control, the usual times of application being spring and fall. It is desirable to harvest citrus fruit before oil is applied, because oil inhibits degreening (disappearance of green rind color).

The work of Gray & deOng (1926), of deOng *et al.* (1927), and of Smith (1932) led to standards for minimum unsulfonated residue and percentage of oil distilled at 636° F. for five classes or grades of foliage spray oils. This standardizat'on cleared up some of the confusion regarding pest-control efficiency of various oils and resulted in reduced plant injury. Although compliance with accepted practice for application of oil sprays has to some degree minimized unfavorable responses, increased leaf drop and fruit drop may occur. These are the most obvious reponses to oil sprays. The influence of these sprays on fruit yield is a more important response for consideration, however, since this factor integrates numerous tree responses: for example, leaf and fruit drop, stem dieback, fruit set, and fruit size. In addition, to assess the effects of a spray treatment, fruit quality must be considered.

In 1925, prior to the standardization of spray oils in California, Smith (1932) noted reduction in the amount of bloom and the set of oranges on some oil-sprayed trees. However, he reported that this situation was greatly improved after the introduction of light, light-medium, and medium oil emulsions, and the adjustment of the timing of the apllications. Woglum (1930) concluded that there was "no outstanding or even great" difference in production between oil-sprayed orange trees and those fumigated with hydrogen cyanide. Although hundreds of acres of citrus were sprayed with oil commercially in Florida without damage and with excellent scale control, Ziegler (1939) produced severe leaf and fruit drop through the experimental use of relatively high concentrations of the same oils. As a result of 5 years' trials of oil sprays vs. fumigation on lemons in California, Newcomb (1947) observed that spraying twice a year, in late spring and in early fall, caused neither lowering of yield nor any marked loss of quality.

Rohrbaugh (1941) observed that oil may fill the intercellular spaces in the leaf and stem tissue of citrus, and that portions of the oil remained in the leaves throughout their lifetime, often more than 2 years.

Some of the undesirable effects on fruit quality reported to result from oil sprays are the following: (1) a reduced percentage of total soluble solids in the juice, (2) an increased percentage of granulation in Valencia oranges, (3) an increased susceptibility of navel oranges to water spot, and (4) a delayed degreening in response to ethylene (Sinclair *et al.* 1941; Bartholomew & Sinclair 1944; Ebeling & Klotz 1936; Ebeling *et al.* 1938; and Winston 1931, 1943).

Preliminary experiments (Stewart & Ebeling 1946) showed that the addition of 2,4-dichlorophenoxyacetic acid (2,4-D) to citrus oil sprays significantly reduced leaf and fruit drop. Cole & Heeley (1947)

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have reported on the similar use of alpha naphthaleneacetic acid as an amendment to oil sprays for summer pest control on apples. They found that the addition of 10 p.p.m. of alpha naphthaleneacetic acid "modified or prevented the shock due to the application of oil and thereby prevented leaf- and fruit-drop."

Results of further studies of effects of 2,4-D when used as an amendment to oil sprays applied to citrus trees for pest control are reported here. These results are based on 63 replicated experiments conducted throughout the various citrus districts of California.

MATERIALS AND METHODS.—Included in these trials were trees of Washington Navel orange, Valencia orange, grapefruit, and lemon—varieties accounting for more than 95 per cent of the citrus acreage in California. Within each variety, four series of experiments were set up, as follows: (1) the 1946 series, in latin-square design; (2) the 1947 series, in randomized block pattern (including one experiment with Mediterranean Sweet orange); (3) the 1948 series, to test the use of 2,4-D in oil sprays on a large (commerical) scale, and to obtain packing-house grading of fruit quality and size; and (4) miscellaneous experiments (1947–1948) of various designs, including growers' test plots, in which the trees ranged in age from 7 to 50 years or more.

In all experiments standard orchard spray equipment was used, operating at a pump pressure of 500 pounds per square inch, with No. 8 discs in the spray guns. Spray applications, when possible, followed irrigation, but were not undertaken if air temperatures were higher, or were predicted to be higher, than the maximum for safety of the trees.[1] A complete, drenching spray was applied. Unless otherwise noted, commercial weed-killing formulations of 2,4-D were used. Concentrations of 2,4-D are given in terms of acid equivalent.

For the 1946 and 1947 series of experiments, finished spray emulsions were prepared according to the tank-mix method (Smith 1932). Standard blood albumin spreader at the rate of 4 ounces per 100 gallons of finished spray mixture was dissolved in the tank in approximately 100 gallons of water. With the agitator in motion and the pump operating under pressure, the specified amount of oil for the spray mixture desired was put in the tank and the water required to bring the mixture up to volume was added. The 2,4-D was then mixed into the emulsion.

In the 1946 experiments, which were in a latin-square design employing one tree per plot, the following five treatments were used:

(1) no oil spray and no 2,4-D (pest control, when required, was obtained by either hydrogen cyanide fumigation or a non-oil spray);
(2) oil spray without 2,4-D;
(3) oil spray plus 0.8 p.p.m. 2,4-D;
(4) oil spray plus 4 p.p.m. 2,4-D; and
(5) oil spray plus 8 p.p.m. 2,4-D.

In these experiments the 2,4-D was added as either the di- or the triethanolamine salt.

In the 1947 experiments, which were in a randomized block design employing four trees per plot in five replications, the following six treatments were used:

(1) no oil spray;
(2) oil spray without 2,4-D;
(3) oil spray plus 8 p.p.m. 2,4-D as the ammonium salt;
(4) oil spray plus 8 p.p.m. 2,4-D as the triethanolamine salt;
(5) oil spray plus 0.8 p.p.m. 2,4-D as the isopropyl ester; and
(6) oil spray plus 4 p.p.m. 2,4-D as the isopropyl ester.

In 1948, when the trees of this (1947) series of experiments were sprayed again, commercial emulsive spray oils[2] were used and treatment 5 was changed from the relatively ineffective 0.8 p.p.m. to 8 p.p.m. 2,4-D added as the isopropyl ester. The amount and form of 2,4-D used in the other treatments remained unchanged.

The large-scale experiments of the 1948 series were based on the use of a commercially prepared 1.75 per cent light-medium emulsive oil to which enough 2,4-D was added to produce a concentration of 4 p.p.m. 2,4-D acid equivalent in the final spray emulsion. The 2,4-D used in this series was a technical grade of isopropyl 2,4-dichlorophenoxyacetate without emulsifier. A sufficient quantity of the ester

[1] The Agricultural Code of California, chapter 1a, section 160.5, authorizes the county agricultural commissioners to set maximum temperatures for oil spray application in the various localities (usually between 85° and 95° F.).

[2] Emulsive and emulsion spray oil formulations were obtained from the following companies: Shell Oil Company, Tide Water Associated Oil Company, California Spray-Chemical Corporation, Leffingwell Company, and Socony-Vacuum Oil Company.

Table 1.—Average fruit yield, fruit drop, and leaf drop per tree from citrus trees sprayed for pest control in late summer (August and September) with oil, without and with 2,4-D added; 1946–1947.

Variety	Number of Locations	Oil Spray		Mean Difference[2]	L.S.D.[3]	
		Without 2,4-D	With[1] 2,4-D		5 Per Cent	1 Per Cent
Fruit Yield (in Field Boxes)						
Washington Navel orange	7	4.66	5.09	0.43*	0.39	0.58
Valencia orange	6	4.04	4.33	0.29	—	—
Grapefruit	4	8.10	8.78	0.68†	0.07	0.13
Lemon[4]	9	1.53	1.70	0.17	—	—
Fruits Dropped						
Washington Navel orange	14	122	59	63	39.96	55.73
Valencia orange	4	77	80	3	—	—
Grapefruit	4	67	36	31	—	—
Lemon	5	32	19	13*	9.82	16.28
Leaves Dropped						
Washington Navel orange	5	219	116	103	7.65	12.69
Valencia orange	5	258	168	90*	73.99	122.72
Grapefruit	4	182	136	46	—	—
Lemon	6	40	18	22*	22.04	36.56

[1] The 2,4-D added at 8 p.p.m., acid equivalent per total volume of finished spray mixture, except when added as the isopropyl ester, at 4 p.p.m., in 1947 experiments.
[2] *=significant at 5 per cent level; †=significant at 1 per cent level.
[3] Dash (—) signifies that mean difference was not statistically significant at 5 per cent level.
[4] Yields for two locations are averages for two consecutive years when the trees were sprayed annually; in other locations yield was determined for intervals up to 6 months after spraying.

was diluted to 5 gallons with the emulsive oil, so that 1 pint of this preparation, added as part of the oil each time the spray mixture was prepared, gave the desired 4 p.p.m. of 2,4-D.

In the miscellaneous series of experiments, various oil formulations, generally of commercial preparation, were applied.

It should be pointed out that most of the non-oil-treated plots required some type of insecticide and were either fumigated with hydrogen cyanide or sprayed with a non-oil material, the treatment depending upon the pest. In all experimental plots economic control of the pests was attempted to minimize differences from insect infestation.

All spray applications were made in late summer (August and September). In the 1946 series spray applications were also made in other complete latin-square plots in the same orchards in early winter (November and December), late winter (February), spring (April), and early summer (June).

In all series of experiments leaf drop was determined by counting the number of mature leaves on the ground within a given area under the tree. The leaves were caught either in boxes or in nets. Within any one experiment leaf-drop counts were comparable, but between experiments they were not always so, because of differences in sampling areas. Counts of immature or young fruits dropped were made in the same manner as for leaf drop. All fruit on the ground under the tree immediately after spraying was removed, and fruit subsequently dropped was counted. In the two 1948 commercial-scale experiments on Washington Navel orange trees, the fruit was classified according to probable cause of drop.

At harvest, production records were obtained as field boxes per tree. The fruits in partly filled field boxes were either counted or estimated to the nearest tenth of a box. As an indication of fruit size, the number of fruits per field box was determined.

EFFECTS OF LATE-SUMMER APPLICATIONS OF OIL SPRAYS.—The results of the late-summer applications of oil sprays, without and with the addition of 2,4-D, in the 1946 and 1947 series of experiments are summarized in table 1. The data were obtained in various localities and show differences in fruit yield, fruit drop, and

leaf drop of the experimental trees of Washington Navel orange, Valencia orange, grapefruit, and lemon.

For purposes of statistical analysis, each location was considered a single replicate, and the data from the various locations were considered together and analyzed according to a randomized block design. In the 1946 series of experiments only the 8-p.p.m. 2,4-D concentration was used in the comparison. In the 1947 series, results obtained from the three forms of 2,4-D that were added to the oil, namely, the ammonium salt, the triethanolamine salt, and the isopropyl ester, were averaged together for each locality. In these experiments the two salts were added at 8 p.p.m., and the ester was added at 4 p.p.m. When the trees were resprayed in 1948, the treatment schedule was revised to include treatment with the ester at 8 p.p.m., for purposes of direct comparison with the salts. In localities where the applications had been repeated annually for two or three years, the yearly results were averaged to provide a single value for the effect of oil containing 2,4-D in that locality.

Fruit Yield.—The addition of 2,4-D to oil sprays applied to Washington Navel orange and grapefruit trees increased the yields significantly by reducing drop of mature fruit (Table 1). Increases in yields of Valencia orange and lemon trees were not significant.

No significant differences in yields of Valencia oranges followed the second or third annual applications of 8 p.p.m. 2,4-D in oil-spray mixtures. It is important to note that 2,4-D apparently had no cumulative detrimental effect on yield.

The effectiveness of the three forms of 2,4-D for increasing yield when added to the oil-spray mixture was evaluated by comparing data from trees of the 1947 series of experiments, resprayed in 1948. Each orchard was used as a replicate without distinction as to whether the trees were navel orange, Valencia orange, or grapefruit. From trees sprayed with oil alone, the mean yeild in field boxes per tree was 5.09. From trees sprayed with oil containing 2,4-D as the isopropyl ester, the mean yield at 4 p.p.m. was 5.75 boxes and at 8 p.p.m., 6.08; with 2,4-D as the ammonium salt, it was 5.49, and as the triethanolamine salt, 5.90 (L.S.D. at 5 per cent, 0.61; and at 1 per cent, 0.83). The oil-spray mixture containing 2,4-D as the ammonium salt was the only one that failed to effect a significant increase in yield. The yield for the mixture containing 8 p.p.m. 2,4-D as the triethanolamine salt was between those for the mixtures containing 2,4-D as the isopropyl ester at 4 p.p.m. and at 8 p.p.m.

Fruit Size.—Oil sprays containing 2,4-D did not significantly increase fruit size, in comparison with non-2,4-D sprays.

Fruit Drop.—Fruit drop was significantly less from Washington Navel orange and lemon trees sprayed with oil containing 2,4-D than from those sprayed with oil alone. Grapefruit, however, failed to show a corresponding statistically significant reduction in fruit drop. This may have been due to the limited number of locations in which experiments with grapefruit were conducted, since the reductions in three of the four locations were significant when the response in each location was analyzed separately.

Valencia orange trees likewise failed to show a reduction in fruit drop, except when the spray was applied on trees bearing mature fruit—a practice which is avoided except for emergency pest control. The failure of 2,4-D, when applied to Valencia orange trees in an oil spray in the late summer, to reduce mature fruit drop 12 to 14 months later may have been due to the long interval between application and fruit drop.

Leaf Drop.—Inclusion of 2,4-D in the oil spray significantly reduced leaf drop from navel orange, Valencia orange, and lemon trees, compared with that from trees sprayed with oil alone (Table 1). The reduction in leaf drop of grapefruit trees was not significant. An example of the leaf drop observed in one experiment following oil sprays without and with 2,4-D is shown in figure 1.

In one of the experiments of the miscellaneous series with lemon trees, it was found that the addition of 8.5 p.p.m. 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) to a 1.67 per cent light-medium emulsive oil spray significantly (at 1 per cent level) reduced leaf drop from 193 leaves per tree, from trees similarly sprayed but without 2,4,5-T, to 110 leaves. The comparative effectiveness of 2,4,5-T and 2,4-D when applied in oil sprays is not known, but when applied in a water spray 2,4,5-T was more effective

Table 2.—Fruit drop per tree of Washington Navel oranges sprayed with oil August 17, 1948, without and with 4 p.p.m. 2,4-D added as the isopropyl ester.

DATE OF COUNT		1–27–49	2–15–49	3–15–49	4–19–49	5–5–49
	Oil-Sprayed					
	Without 2,4-D	15	6	12	12	12
Trees Counted	With 2,4-D	18	9	17	16	16
Fruit Classification		Cumulative Fruit Drop				
Sound	Without 2,4-D	11.2	16.9	23.3	28.0	28.8
	With 2,4-D	1.2	1.3	2.5	3.7	4.3
Mechanical	Without 2,4-D	7.3	8.8	10.1	10.5	10.8
	With 2,4-D	7.2	11.8	13.7	14.5	14.7
Black rot	Without 2,4-D	7.3	9.1	18.0	25.9	29.0
	With 2,4-D	4.3	6.2	12.9	18.5	22.2
Brown rot	Without 2,4-D	1.5	3.2	6.5	8.3	9.1
	With 2,4-D	0.9	2.1	7.9	10.4	11.9
Frozen	Without 2,4-D	10.7	18.3	43.3	54.5	57.9
	With 2,4-D	1.2	7.2	30.8	50.0	55.6
Orangeworm	Without 2,4-D	0.2	0.2	0.3	0.4	0.4
	With 2,4-D	0.2	0.3	0.5	0.9	0.9
Split	Without 2,4-D	3.4	5.2	7.4	8.3	9.2
	With 2,4-D	2.9	4.7	8.5	10.3	11.2
Unknown	Without 2,4-D	0.4	0.6	6.5	9.8	10.3
	With 2,4-D	0.5	0.5	5.9	9.3	10.2
Water spot[1]	Without 2,4-D	—	1.3	11.0	23.9	29.9
	With 2,4-D	—	0.8	7.8	17.9	21.8
Total	Without 2,4-D	42.0	63.6	126.4	169.6	185.4
	With 2,4-D	18.4	34.9	90.5	135.5	152.8
		Periodic Fruit Drop				
Culls[2]	Without 2,4-D	30.8	15.9	56.4	38.5	15.0
	With 2,4-D	17.2	16.4	54.4	43.8	16.7

[1] Classification added after first count.
[2] All dropped fruits except those classed as sound.

than 2,4-D in delaying abscission of lemon fruit and leaves and increasing fruit size (Stewart & Hield 1950; Erickson, unpublished). In addition, 2,4,5-T was more effective than 2,4-D in increasing storage life of lemons (Stewart 1949). For these reasons, further investigation of 2,4,5-T as an amendment for oil sprays seems to be warranted.

Commercial-Scale Experiment.—Results from one of the Washington Navel orange orchards used in the commercial-scale experiments in 1948 are presented in detail. This grove, which is located in Riverside and consists of 33 rows of 31 trees each, was divided into 3-row plots. On August 17, 1948, alternating plots were sprayed with oil alone and with oil containing 4 p.p.m. 2,4-D as the isopropyl ester.

To determine the value of following the oil sprays with a secondary preharvest 2,4-D water spray, the third tree in every row was given a drenching water spray containing 8 p.p.m. 2,4-D on January 19, 1949. The dropped fruit under these trees and under the fifth tree in every row was removed immediately after spraying. The fifth tree was not sprayed with 2,4-D, but served for comparison with the third tree. At this time the average number of fruits per tree on the ground under the trees sprayed in August with oil alone, was 45.7, whereas the average number of fruits under the trees sprayed with oil containing 2,4-D was only 20. The force of the spray caused an average drop of 7 fruits per tree from the group sprayed in August with oil alone, compared with 3 fruits per tree from the group sprayed with oil plus 2,4-D.

On January 27, 1949, the fruit on the ground underneath the seventh tree in each row was classified according to the probable cause for dropping. Where necessary, the fruits were cut open to determine such causes as black rot and frost injury. Fruits having no visible external or internal defects, and determined to be edi-

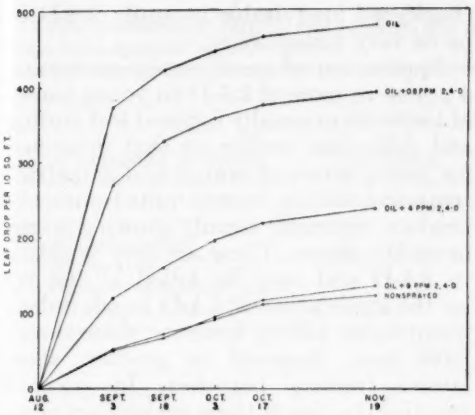

FIG. 1.—Drop of mature leaves from Valencia orange trees (Highgrove, California) sprayed August 12, 1946, without and with various concentrations of 2,4-D in 1.67 per cent light-medium tank-mix oil. Each point on the curves represents the average count for five trees.

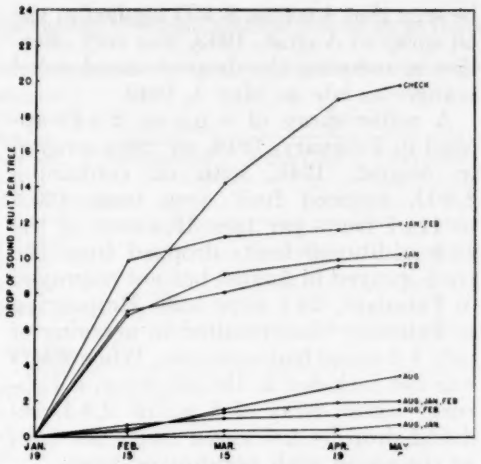

FIG. 2.—Fruit drop from Washington Navel orange trees given various spray treatments. The designation "Aug." indicates that the trees represented by the specified curve were sprayed in August, 1948, with 4 p.p.m. 2,4-D as the isopropyl ester in 1.75 per cent light-medium emulsive oil. "Jan." and "Feb." indicate that the trees represented were given water sprays of 8 p.p.m. 2,4-D as the isopropyl ester in those months. "Check" trees received no 2,4-D, but were sprayed in August with oil spray alone.

ble by taste test, were classified as marketable or "sound." Those having the button attached and showing evidence of having been broken off by wind or orchard equipment were listed as "mechanical." The terms "black rot" or "brown rot" were usually assigned to fruits showing those characteristics. It was not possible to determine whether brown rot preceded abscission. Larvae of "orangeworm" (probably orange tortrix) were recognized as a cause of fruit drop when the rind had evidently been penetrated by a larva, although fungus infection following the insect injury seemed to be the more direct cause of abscission. Similarly, "split" fruits were usually invaded by microorganisms that seemingly hastened abscission. Although "water spot" is not of normal occurrence in the Riverside area, typical necrotic areas developed in the rind after the cold, wet weather of January, 1949. Dropped fruits too badly decayed to permit classification were listed as "unknown."

Cumulative fruit drop per tree during the harvest season is shown in table 2. From trees sprayed in August with oil alone, the drop of sound fruit was 28.8 fruits per tree, and from those sprayed with oil containing 4 p.p.m. isopropyl ester of 2,4-D, it was 4.2. On the basis of total fruit drop for the season, this amounted to 15.5 per cent and 2.8 per cent, respectively. If all dropped fruits except those classified as "sound" were considered as "culls," the trees sprayed with oil containing 2,4-D dropped 17.2 culls per tree up to January 27, 1949 (about three weeks after the freeze), whereas trees sprayed with oil alonge dropped 30.8. At subsequent counts, however, it was found that the trees sprayed with oil containing 2,4-D dropped more cull fruits than those sprayed with oil alone, except for the interval from February 15 to March 15, 1949; so that by May 5, 1949, the total amounts of culls dropped per tree were 156.6 and 148.5, respectively, from the trees sprayed with oil, without and with 2,4-D.

During the middle of February, 1949, all the trees in the north 18 rows of the orchard were sprayed with a water solution containing 8 p.p.m. 2,4-D and the usual zinc foliage spray. The purpose of this treatment was to allow a late harvest, May 5, 1949, without the usual fruit drop. The trees in the south 15 rows were harvested on March 3, 1949, with the exception of the third, fifth, and seventh trees in each row. It was thus possible for fruit-drop counts to continue until May 5 for all the various spray combinations. The results of these counts are presented in figure 2. From these data it may

be seen that 4 p.p.m. 2,4-D applied in the oil spray in August, 1948, was very effective in reducing the drop of sound navel oranges as late as May 5, 1949.

A water spray of 8 p.p.m. 2,4-D applied in February, 1949, on trees sprayed in August, 1948, with oil containing 2,4-D, reduced fruit drop from 140.3 to 114.7 fruits per tree. However, of the 25.6 additional fruits dropped from the trees sprayed in August but not resprayed in February, 24.1 were culls. Respraying in February thus resulted in a saving of only 1.5 sound fruits per tree. When 2,4-D was not included in the oil spray, a February water spray of 8 p.p.m. 2,4-D reduced drop by 9.6 sound fruits per tree, as compared with nonsprayed trees.

Data on fruit production, size, and quality were obtained from the packing house. In comparison with fruit from trees sprayed with oil alone, the total amount of fruit in every quality grade (first grade, second grade, juice, and culls) was increased at both harvests as a result of the addition of 2,4-D to the oil spray. The increase in first-grade, second-grade, juice, and cull fruits per 100 trees amounted to 20.5, 6.2, 3.2, and 2.7 boxes, respectively, at the first harvest, and to 23.4, 0.6, 35.2, and 4.0 boxes, respectively, at the second harvest.

There were no consistent differences in sizes of fruits from trees sprayed with oil alone or with oil containing 2,4-D.

Leaf Curling.—As reported earlier (Stewart & Ebeling 1946), an oil spray containing 4 p.p.m. or more of 2,4-D applied on trees with "soft," young, rapidly expanding leaves and stems generally induced leaf curling and often caused stem distortion. Subsequent cycles of foliage growth were normal, except for an occasional twig showing slight leaf modifications on one flush of growth. The leaf curling was minimized or eliminated by spraying between growth flushes when the least new growth was present. In no case was leaf curling found to lower fruit production or quality. It should be considered, however, that new leaves probably constitute a much greater proportion of the total foliage on very young trees than on older trees. Accordingly, if leaf curling induced by 2,4-D on new leaves reduced their efficiency, the effect would be more significant on young trees than on old ones. For this reason, it was considered inadvisable to apply 2,4-D in oil on very young trees.

Application of an oil spray containing 4 p.p.m. or more of 2,4-D on young leaves of lemon trees usually induced leaf curling and distortion similar to that described for young leaves of orange and grapefruit trees. In addition, lemons quite commonly produce vigorous, rapidly growing whips or sucker shoots. These are very sensitive to 2,4-D and may be killed at the tip by the application of 2,4-D in oil. Subsequent to the killing, however, these shoots have been observed to produce short lateral fruiting branches. In orchard practice the tips of these suckers are often cut off to accomplish the same purpose.

Oil-Treated vs. Non-Oil-Treated Trees.—The 1946 and 1947 series of experiments included a treatment without oil. In table 3 fruit yield, fruit size, fruit drop, and leaf drop of non-oil-treated trees are compared with those of trees sprayed with oil (without 2,4-D). No significant differences were observed for yield, fruit size, or fruit drop of Washington Navel orange, Valencia orange, grapefruit, or lemon trees. Leaf drop from Valencia orange and lemon trees was significantly greater from

Table 3.—Average fruit yield, fruit size, fruit drop, and leaf drop of citrus trees not oil-treated or sprayed with oil for pest control; 1946–1947.

Variety	Number of Locations	Non-Oil-Treated	Oil-Sprayed	Mean Difference
Fruit Yield (Field Boxes/Tree)				
Washington Naval orange	4	4.47	4.44	0.03
Valencia orange	5	4.41	3.89	0.52
Grapefruit	3	6.93	7.27	0.34
Lemon	2	1.43	1.53	0.10
Fruit Size (Fruit/Field Box)				
Washington Naval orange	4	170	166	4
Valencia orange	4	234	233	1
Grapefruit	3	68	67	1
Lemon	2	247	239	12
Fruit Drop/Tree				
Washington Naval orange	4	48	47	1
Valencia orange	5	73	86	13
Grapefruit	2	100	120	20
Lemon	2	77	104	27
Leaf Drop/Tree				
Washington Navel orange	4	135	170	35
Valencia orange	5	113	258	145[1]
Grapefruit	3	50	74	24
Lemon	4	47	72	25[1]

[1] = significant at 5 per cent level. (If leaf counts in the two locations where tank-mix oil spray was applied on these trees are omitted, however, data show no significant different between drop of non-oil-treated and oil-sprayed trees.)

Table 4.—Effect of various spray treatments[1] on percentage of soluble solids in juice of citrus fruits from trees sprayed for pest control.

Treatment of Trees	Number of Locations	Average Soluble Solids in Juice	Mean Difference[2]	L.S.D.[3] 5 Per Cent	L.S.D.[3] 1 Per Cent
Washington Navel Oranges					
Not-oil-treated	4	12.48%	0.80*	0.66	1.21
Oil-Sprayed	4	11.68			
Oil-sprayed without 2,4-D	4	11.68	0.43	—	—
Oil-sprayed with 2,4-D	4	12.11			
Valencia Oranges					
Not oil-treated	2	13.30	0.18	—	—
Oil-sprayed	2	13.12			
Oil-sprayed without 2,4-D	2	13.12	0.26	—	—
Oil-sprayed with 2,4-D	2	13.38			
Grapefruits					
Not oil-treated	2	10.20	0.43	—	—
Oil-sprayed	2	9.77			
Oil-sprayed without 2,4-D	3	9.73	0.22*	0.12	0.29
Oil-sprayed with 2,4-D	3	9.95			

[1] The 2,4-D added at 4 p.p.m. as the isopropyl ester, or at 8 p.p.m. as the diethanolamine salt, acid equivalent per total volume o finished spray mixture.
[2] *=significant at 5 per cent level.
[3] Dash (—) indicates that mean difference was not significant at 5 per cent level.

the trees sprayed with oil than from the non-oil-sprayed trees. If, however, the figures are recalculated, omitting those locations where tank-mix oil spray was applied, no significant differences are found, since the tank-mix oil spray induced greater leaf drop than the commercially prepared emulsive spray-oil formulations. There were no significant differences in leaf drop from oil-treated Washington Navel orange and grapefruit. and trees not so treated.

Fruit Quality.—In the course of the late-summer oil-spray experiments, determinations of fruit quality were made. The data on percentages of total soluble soilds of the juice are summarized in table 4. These results indicate that the percentage of total soluble solids of the juice was significantly lower in navel oranges from trees sprayed with oil (tank-mix method) for pest control than from trees not oil-treated. However, the differences between the means for similar comparisons made for Valencia oranges and for grapefruit were not significant. The juice of grapefruit from trees treated with oil-spray mixtures containing 2,4-D had a significantly higher percentage of total soluble solids than that of grapefruit from trees treated with oil spray to which 2,4-D was not added. The differences between the means for similar comparisons for both varieties of oranges were not significant. This may indicate either no real effect of 2,4-D as a means of alleviating the decrease in the percentage of total soluble solids of oranges sprayed with oil for pest control, or inadequate sampling. However, since the use of 2,4-D a an amendment for oil sprays was observed to have some influence on the percentage of total soluble solids in oranges, further investigation may be warranted.

No significant differences between treatments were found in comparisons of percentages of total acids of the fruits. Percentages of juice, rind, and rag[1] showed no significant differences in fruit of oranges or grapefruit from non-oil-sprayed trees or from trees sprayed with oil with or without 2,4-D, regardless of the season of application.

In these experiments application of 2,4-D-oil sprays during the spray season had no significant effect on the time of disappearance of the green rind color of

[1] Rag, or pulp, as determined here, was the material which failed to pass through the vibrating screen of an electrical juice extractor.

oranges and grapefruit, or on the development of water spot of the rind of navel oranges.

In July, 1948, Stewart & Riehl suggested the commercial use of 2,4-D as an amendment to oil sprays used for citrus pest control. Directions were given for use of the ester form of 2,4-D with emulsive-type spray oils and of the salt form with emulsion-type spray oils. In practice, however, the form of 2,4-D used has made no appreciable differences in the oil-depositing characteristics of spray emulsions prepared with either emulsion or emulsive oils. Further experience will probably indicate that the esters of 2,4-D are preferable to the salts for addition to all oil sprays, since the esters are oil-soluble and presumably will penetrate the tissue along with the oil. The 2,4-D esters are also more volatile than the salts and hence probably do not remain for as long periods on the leaf surface, later to penetrate and induce distortion of new growth. No data on the relative leaf-curling effect of salts and esters of 2,4-D have been obtained.

Effects of Oil-Spray Applications at Other Seasons.—To determine whether the inclusion of 2,4-D in the oil spray might reduce the unfavorable effects of oil sprays applied at other seasons than late summer, experiments were established at intervals throughout 1946. The same design, same treatments, and the same groves were used as were employed in the 1946 series of latin-square experiments described above, but in addition to the usual late-summer oil spray, applications were made in the early winter (November or December), late winter (February), spring (April), and early summer (June). At each of these seasons a separate group of trees within the grove was sprayed.

Except in late summer (the conventional spray period) or in the spring (April), applications of spray oil without or with 2,4-D did not influence the yield of oranges. Oil treatments applied to orange trees in the spring caused reductions in yield in comparison with that of non-oil-treated trees, and in three cases out of five these reductions were significant. When 2,4-D was added to the oil spray, the yield was reduced significantly, in comparison with that of non-oil-treated trees, in five out of five cases, and in comparison with trees sprayed with oil alone, in two out of five cases. Yield data were not obtained for grapefruit.

Spring and summer applications of 2,4-D-oil sprays significantly increased the fruit size of Valencia oranges in an experiment at Irvine, but failed to do so in another test at Highgrove. The spring application of 2,4-D-oil spray on Washington Navel orange trees also resulted in a significant increase in fruit size. At no other season was a significant increase in fruit size noted in response to application of oil containing 2,4-D. Fruit-size data were not obtained for grapefruit.

Drop of mature fruit was generally less from trees sprayed with oil containing 2,4-D than from those sprayed with oil alone. However, the differences were statistically significant in only two of the applications. Washington Navel oranges and grapefruit showed the greatest reduction in mature fruit drop in response to the 2,4-D, and Valencia oranges showed the least.

Leaf drop was usually less from the tres sprayed with oil containing 2,4-D than from those sprayed with oil alone. The significance of these differences was not determined.

MISCELLANEOUS EXPERIMENTS WITH OIL SPRAYS ON TREES BEARING MATURE FRUIT.—Although it is not usual practice to apply an oil spray to trees bearing fully colored mature fruit, it is sometimes more desirable to make such an application than to allow the continued insect pest damage that would otherwise occur. In 1947, and again in 1948, to control black scale *Saissetia oleae* (Bern.), in the Garden Grove district, it was necessary to apply oil sprays to Valencia orange trees bearing mature fruit. To compare results without and with the addition of 4 or 8 p.p.m. 2,4-D to these oil sprays, seven "miscellaneous" experiments were performed. Six of these were in the Garden Grove district, and the seventh was in the San Juan Capistrano district. It was found that the addition of 2,4-D significantly (at the 5 per cent level) reduced fruit drop from 122 to 75 fruits per tree.

To determine whether a significant reduction of fruit drop would result if an oil spray without 2,4-D was applied to trees previously sprayed with a 2,4-D water spray, two additional experiments

were made in a grove near San Juan Capistrano. All trees were bearing mature fruit when the oil spray was applied.

In the first experiment, fruit-drop counts during the interval from June 6, 1947, when the trees were sprayed, to November 5, 1947, indicated that the 2,4-D water spray significantly reduced fruit drop on two counting dates before the oil application on September 19. After application of the oil spray, there was no evidence of reductions in fruit drop associated with 2,4-D.

In the second experiment, it was found that the trees sprayed with the water solution containing 8 p.p.m. 2,4-D as the isopropyl ester and then, a week later, sprayed with oil, showed a 38 per cent reduction in fruit drop, compared with trees similarly sprayed but without 2,4-D. This reduction was significant at the 5 per cent level. The same concentration of 2,4-D in an oil spray would be expected to give a greater reduction when applied over mature fruit.

Results of these two experiments indicate that to obtain the maximum effect of 2,4-D in counteracting fruit drop resulting from the use of oil sprays, it is desirable to add the 2,4-D directly to the oil spray.

MEDITERRANEAN SWEET ORANGE EXPERIMENT.—Fruit from a 40-year-old grove of Mediterranean Sweet orange trees near Bryn Mawr, California, is generally picked in May, near the end of the navel-harvesting season and at the beginning of the Valencia season. To study the effects of adding 2,4-D to oil spray applied on Mediterranean Sweet orange, the trees in this grove were sprayed on October 31, 1947. A randomized block design was used with one tree per treatment and four replications. A spray of 1.8 per cent light-medium emulsive oil was used alone or with 8 p.p.m. 2,4-D added as the ammonium salt, diethanolamine salt, isoprophyl ester, or butyl ester (technical grade). Fruits dropped per tree after applications of these materials (counted on May 4, 1948) were, respectively, 238.2, 83.5, 89.7, 58.8, and 35.2. (L.S.D. at 5 per cent, 34.1; and at 1 per cent, 47.2). As previously found for oranges and grapefruit, the esters were more effective in reducing fruit drop than either of the salts.

SUMMARY AND CONCLUSIONS.—From 1946 through 1949, 63 replicated field experiments were conducted in representative citrus-growing districts of California to determine the various effects of 2,4-D added at concentrations of 0.8 to 8.0 p.p.m. to oil sprays used for citrus pest control. The trees varied in age from 7 to an estimated 50 years or more, and included Washington Navel orange, Valencia orange, grapefruit, and lemon. The finished spray mixtures were prepared by the tank-mix method or by the use of emulsive or emulsion oil formulations. In most experiments 2,4-D in various forms was added as it is formulated for weed-killing sprays. A number of the plots were sprayed once annually for 2 successive years; a few of them were sprayed once annually for 3 years.

It was found that addition of 4 or 8 p.p.m. 2,4-D to the oil spray mixture: (1) increased the fruit yield of navel orange trees and grapefruit trees; (2) reduced the drop of mature fruit from navel orange trees and lemon trees; (3) was more effective in reducing the drop of "sound" navel oranges than of "culls"; (4) reduced the drop of immature fruit from navel orange trees; (5) reduced leaf drop from navel orange, Valencia orange, and lemon trees; (6) increased the percentage of total soluble solids in the juice of grapefruit, over that of grapefruit sprayed with oil alone; (7) induced a deformation and curling of any young leaves, which did not, however, lower fruit yield or quality; (8) did not affect yield from Valencia orange trees when applied annually at 8 p.p.m. for 3 successive years.

In comparison with non-oil-treated trees, no significant differences due to applications of oil sprays were observed for yield, fruit size, fruit drop, or leaf drop from navel orange, Valencia orange, grapefruit or lemon trees sprayed in late summer with emulsive or emulsion oil formulations. However, when oil sprays preparee by the tank-mix method were used, significant increases in leaf drop were found for both Valencia orange and lemon trees. A significant reduction in the percentage of total soluble solids was found in the juice of fruit from navel orange trees sprayed with oil applied as tank mix.

Application of 2,4-D oil spray at other seasons than the customary late-summer spray period reduced fruit and leaf drop. Fruit yields were reduced as a result of spring applications of oil spray mixtures without or with 2,4-D, but this effect was not observed at other seasons.

A 2,4-D water spray applied a week or more prior to an oil spray was ineffective in reducing fruit drop caused by oil spray applied on trees bearing mature fruit. To obtain maximum effectiveness in counteracting fruit drop resulting from the use of oil sprays it is therefore apparently desirable to add the 2,4-D directly to the oil spray.

In one experiment with Mediterranean Sweet orange trees, it was found that application of oil containing 8 p.p.m. 2,4-D reduced mature fruit drop six months later, in comparison with fruit drop from trees sprayed with oil alone.

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Tree Trunk Application as a Possible Method of Using Systemic Insecticides on Citrus[1]

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Since the discovery by Schrader (1947) that certain phosphate materials toxic to insects are translocated in plants, considerable interest has developed in these systemic insecticides. Ripper *et al.* (1949, 1951) in England, and Wallace (1951) and Ivy *et al.* (1950) in the United States have shown that both soil and foliage applications of octamethyl pyrophosphoramide are highly effective in controlling certain insects and mites on annual crops. Under experimental conditions, Metcalf & Carlson (1950) found that applications of these systemic insecticides to the soil resulted in a high mortality of mites on the follage of citrus trees.

These systemic insecticides offer two outstanding possibilities for improving pest control on citrus. First, insecticide distribution in the plant may eliminate the necessity for the slow and expensive methods required to obtain complete spray coverage of leaves and fruit. Secondly, application may be made in such a way that the toxic materials are translocated to the injurious insects or mites. Under the latter conditions it is not likely that natural enemies of these pests would be contacted by either the spray or its residue.

Boyce (1950), DeBach (1951), and others have discussed the importance of natural enemies in the control of citrus pests. When systemic insecticides that are toxic to insects and mites are applied to leaves and fruit, they appear to influence the populations of natural enemies adversely. Applications on tree trunks may make it possible to use these insecticides without injury to the beneficial insects which are so often killed by conventional treatments of non-seclective insecticides.

The direct application of an insecticide to the trunks of citrus trees has these advantages: it does not require the use of heavy equipment, which is often undesirable in citrus groves; and local infestations, which are often the foci for general pest populations, can be readily treated. Techniques for applying systemic insecticides to tree trunks, and initial results for control of mites injurious to citrus, are herein reported.

Materials and Methods.—Schradan (octamethyl pyrophosphoramide)[2] and a commercial compound, Systox, principally the diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol,[3] were applied to citrus trees in the following three ways: (1) a saturated cotton or flannel band was wrapped around the trunk, (2) the insecticide was painted on the trunk, or (3) concentrate formulations were sprayed on the trunk and bases on primary limbs.

The bands used in these tests were made of flannel cloth or of 0.5-inch-thick absorbent cotton. These bands were of different widths and were sufficiently long to encircle the trunk. Pliofilm strips 3 inches wider than the bands were placed over them to reduce evaporation of the insecticide, and string wrapped around the tree trunk served to hold the bands in position.

Applications made with a paint brush were a formulation containing 50 per cent active ingredients, or a dilution of this concentrate with triethanolamine. For application as a spray to the trunk and base of limbs, the 50 per cent emulsive formulation was diluted with water. Sprays were applied by means of a 3-gallon garden sprayer, using a fan-type spray nozzle. No preparation of tree trunks was made except to remove loose dirt or bark. Conventional applications used as a basis of comparison were applied to trees as full-coverage sprays employing conventional high-presure spray equipment and manually operated spray guns.

Populations of citrus red mite, *Paratetranychus citri* (Mc.G.), were evaluated by counting the number of adult mites on 32 leaves per tree (Jeppson 1951). Populations of citrus bud mite, *Aceria sheldoni* (Ewing), were evaluated by ascertaining

[1] Paper from University of California Citrus Experiment Station, Riverside, California.

[2] Supplied as a 50 per cent emulsive formulation by The Dow Chemical Company, Midland, Michigan.

[3] Supplied as a 50 per cent emulsive formulation by the Pittsburgh Agricultural Company, Neville Island, Pa.

Table 1.—Toxicity of leaves and fruit of lemon trees to citrus red mite, and of buds to citrus bud mite, after trunk applications of Systox made October 25, 1951, by various methods.

Treatment Material				Citrus Red Mites		Per Cent Buds Infested with Citrus Bud Mite on Dec. 6[3]
Systox (50% Emulsive), Ounces per Tree	Additive		Method of Application[1]	Per Cent Mortality on Fruit Samples[2] Picked		
	Kind	Ounces per Tree		Nov. 1	Nov. 8	
0.5	None	—	Painted on trunk	100	100	0
1.0	Triethanolamine	4	6 in. Cotton band	60	100	0
2.0	Triethanolamine	3	6 in. Cotton band	88	100	0
4.0	Triethanolamine	1	6 in. Cotton band	100	100	0
2.0	Triethanolamine	8	12 in. Cotton band	23	100	1
2.0	None	—	2.5 in. Cotton band	62	100	0
2.0	Water	3	6 in. Cotton band	48	100	0
0.5	None	—	Full-coverage spray	—	100	30
1.0	None	—	Full-coverage spray	—	57	24
None	Triethanolamine	5	6 in. Cotton band	16	50	56
None	Water	5	6 in. Cotton band	5	38	88
None	None	—		2	13	82

[1] For fuller description of methods, refer to text.
[2] Fruits brought to laboratory, infested with 25 mites each, and held for 48 hours before mortality counts.
[3] Of 75 buds examined.

the percentage of infested buds (Jeppson 1952), five buds on each of 15 terminals being examined per tree. Fruits for laboratory biological assays were picked at intervals after treatment and infested with 25 adult citrus red mites each.

Three groves were used in these exploratory experiments. The initial tests (Table 1) employed small Eureka lemon trees in Ventura County. Twelve treatments in which Systox dosages ranged from 0.5 to 4 ounces per tree were applied to nonreplicated single-tree plots by using saturated bands, by painting the tree trunks, or by means of full-coverage sprays. In a second experiment (Table 2) dosages of Systox and Schradan ranging from 0.5 to 4 ounces per tree were applied by the three methods of trunk treatment and by full-coverage sprays to 30-year-old

Table 2.—Toxicity of leaves and fruit of lemon trees to citrus red mite after trunk applications of Systox and Schradon on November 9, 1951 by various methods.

Treatment Material					Average No.[3] of Live Adult Mites on Nov. 27 per		Per Cent Mortality of Mites on Fruit Samples[4] Picked	
Insecticide		Additive						
Kind[1]	Dosage per Tree	Kind	Ounces per Tree	Method of Application[2]	8-Fruit Sample	32-Leaf Sample	Nov. 20	Nov. 28
Systox	0.5 oz.	Triethanolamine	2.5	Painted on trunk	0	0	91	—
Systox	1.0 oz.	Triethanolamine	2.0	Painted on trunk	0	0	91	56
systox	2.0 oz.	Triethanolamine	1.0	Painted on trunk	0	0	100	88
Systox	4.0 oz.	None	—	Painted on trunk	0	0	74	54
Systox	0.5 oz.	Triethanolamine	0.5	3 in. Flannel band	0	0	—	—
Systox	1.0 oz.	None	—	3 in. Flannel band	0	0	85	69
Systox	4.0 oz.	None	—	9 in. Flannel band	0	0	100	86
Systox	2.5 oz.	None	—	6 in. Flannel band	0	0	81	70
Systox	—	Triethanolamine	6.0	3 in. Cotton band	0	0	—	23
Systox	0.5 oz.	None	—	Full-coverage spray	0	0	—	—
Systox	1.0 oz.	None	—	Full-coverage spray	0	0	—	93
OMPA[5]	2.0 oz.	Triethanolamine	2.0	Painted on trunk	10	5		
OMPA	6.0 oz.	Triethanolamine	1.0	Painted on trunk	2	0		
OMPA	6.0 oz.	Triethanolamine	2.0	3 in. Cotton band	1	0		
OMPA	3.0 oz.	Triethanolamine	1.0	9 in. Flannel band	9	2		
OMPA	1.0 oz.	None	—	Full-coverage spray	0	0		
OMPA	2.0 oz.	None	—	Full-coverage spray	0	0		
P-chlorophenyl p-chlorobenzene sulphonate	1.0 oz.	None	—	Full-coverage spray	0	0		
Oil (light-medium)	1.75 pt.	None	—	Full-coverage spray	0	0		
Untreated	—	—	—		18	13		

[1] Unless otherwise specified, a 50% emulsive formulation was used.
[2] For fuller description of method, refer to text.
[3] Average from four replicates of single-tree plots.
[4] Fruits brought to laboratory, infested with 25 mites each, and held for 48 hours before mortality counts.
[5] Technical material.

Eureka lemon trees in Orange County. Applications were made to single-tree plots and replicated four times. In the same district 15-year-old Valencia orange trees received a similar dosage range of Systox and Schradan applied by painting and spraying the tree trunks, as well as by full-coverage sprays (Table 3). Plots containing four trees were each replicated four times in this experiment.

RESULTS.—The initial reductions in citrus red mite populations on trees treated with Systox and Schradan and the toxicity of fruit picked from these trees, are reported in tables 1, 2, and 3. Results of Systox treatments on citrus bud mite are tabulated in table 1.

Field observations indicated that in the fall 10 to 14 days were required after trunk applications of Systox before a high mortality of citrus red mite occurred. In these experiments sufficient Systox was apparently absorbed through the citrus tree trunks and translocated to leaves, fruit, and buds to affect a high mortality of the mites studied.

Mortalities of adult citrus red mite from laboratory biological asays made on fruit picked from Systox-treated trees varied considerably with the dosage and method of application. Mortalities were generally higher with increased dosages, but were no greater when the Systox was applied by full-coverage sprays than when it was applied by some of the trunk treatments.

The Ventura County lemon grove (Table 1) was heavily infested with citrus bud mite. In this experiment Systox did not control populations of the bud mite so effectively as it controlled citrus red mite. However, trunk applications resulted in a reduction of citrus bud mite populations equal to that provided by full-coverage sprays.

At equivalent dosages, Schradan was less effective than Systox in control of citrus red mite, regardless of the method of application. Trunk applications of this material resulted in inadequate control of citrus red mite populations.

SUMMARY.—Application of concentrate formulations of Systox (principally the diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol) to trunks of citrus trees resulted in a high mortality of the citrus red mite, *Paratetranychus citri* (McG.), on the leaves and fruit, and some mortality of the citrus bud mite, *Aceria sheldoni* (Ewing), in citrus buds. Several methods of trunk application are described, and the resulting mite mortalities are reported. Schradan (octamethyl pyrophosphoramide) applied by the same methods resulted in less effective mite mortality than Systox. Outstanding advantages of the tree-trunk method of application are indicated.

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Combination Insecticide-Fungicide Seed Treatments for Corn[1]

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Experiments on the treatment of seed corn with insecticides can be divided into those which have to do with the effects of this type of insecticide placement on soil insects and those which deal with the biological effects of the insecticide on the seed.

This paper deals with the second aspect of the problem, especially with the effects of different dosages of cholorinated hydrocarbon inseciticdes on seed corn of three moisture percentages all stored at three temperatures. Because it is almost a universal practice to treat seed corn with a fungicide, it also becomes necessary to determine any interaction of fungicidal and insecticidal seed treatments when the two are used simultaneously.

Seed corn (at 2, 10, and 14 per cent moisture) was treated with lindane, aldrin, and methoxychlor respectively and stored for forty weeks at 6°, 20°, and 30° C. The effects of these chemicals on the seed were determined principally by periodic germination tests in a greenhouse bench. Green weights of the tops were also determined at the time of the last (fortieth week) germination test.

Table 1 shows the pooled means of all emergence tests for each chemical expressed in percentage of the comparable data for the (untreated) controls, but omitting those where molds developed.

Table 1.—Data on emergence and green weights of seedlings from insecticide-treated seed corn in the absence of mold growth.

	Per Cent[1] of the Control				
	Emergence				Green Wt. of Tops
	Storage Period in Weeks				
Treatments	0	10	24	40	40
Methoxychlor	100.3	98.1	98.1	98.6	96
Aldrin	101.6	100.3	98.1	92.3	86
Lindane	92.6	97.7	86.2	85.3	55

[1] Each figure deals with 600 treated and 600 non-treated seeds.

Methoxychlor-treated seed corn (1.5 oz. of 50 per cent wettable powder per bushel) was not appreciably injured during forty weeks of storage. Both untreated and methoxychlor-treated seed at 14 per cent moisture were injured by mold development in storage at 30° C. by the tenth week, and at 20° C. by the twenty-fourth week.

Aldrin-treated seed corn (3 oz. of 25 per cent aldrin equivalent wettable powder per bushel) showed no evident injury until forty weeks of storage. Injury was greater at the high temperatures than at the low. Molds developed on the controls of the 14 per cent moisture corn stored at 30° C. by the tenth week, but the aldrin treatment retarded mold development through the twenty-fourth week of storage. Green weights of seedlings from aldrin-treated seed stored for forty weeks were 86 per cent of those from the untreated seed in the experiment.

Lindane-treated seed corn (1½ oz. of 75 per cent wettable powder per bushel) showed definite injury in storage by the twenty-fourth week. Storage temperatures had very little influence on the results, except in the 14 per cent corn where molds developed. Both 2 per cent and 14 per cent moisture corn showed lower emergence percentages than the 10 per cent corn. Green weights of seedlings from lindane-treated seed stored for forty weeks were 55 per cent of those from untreated seed in the experiment.

Field Experiments.—Three dosages of lindane, aldrin, methoxychlor, and dieldrin, respectively, were applied to one quart lots of seed corn which were then stored for twelve weeks. At planting time a duplicate series of treatments was made. Half of each of these lots of stored and non-stored corn was treated with a fungicide (Arasan), and all treatments plus the controls were planted in six replications at each of two locations. Records were made on both stand and yield, and an analysis of covariance was computed on these data. Tables 2 and 3 show results of this experiment.

Treatment of seed with methoxychlor

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Table 2.—Mean number of plants in control plots (seed not treated and seed treated only with fungicide), and increases or decreases in number of plants per plot following the use of insecticide seed treatments (6 replications, 15 hills of 4 kernels each in each plot). Ames and Kanawha, Iowa—1951.

Insecticide Dosage (oz./bu.[1])	Treated Seed Stored 12 Weeks		Seed Treated Just Before Planting	
	Without Fungicide	With Fungicide	Without Fungicide	With Fungicide
	Lindane—Kanawha			
None	51.7	54.0	51.3	51.3
0.5625	−1.2	−0.5	0.5	2.9
1.125	−4.5[2]	−3.9	0.5	0.9
2.25	−9.7	−4.3[2]	−2.5	−3.0
	Lindane—Ames			
None	54.2	50.4	53.5	53.7
0.5625	−2.0	1.8	−2.3	1.3
1.125	−6.1[3]	0.6	−3.5	0.1
2.25	−8.2[3]	−4.2[2]	−5.8[2]	−4.5[2]
	Aldrin—Kanawha			
None	53.5	51.2	53.0	53.8
0.375	−4.0[2]	2.6	−1.7	−0.6
0.75	−2.6	−0.4	−1.9	1.3
1.5	−4.3[2]	1.8	−1.4	−1.3
	Aldrin—Ames			
None	56.4	54.0	52.5	52.0
0.375	−2.2	−2.0	−1.0	1.8
0.75	−3.0	−2.8	−4.0	0.8
1.5	−4.0[2]	−1.6	−3.2	−1.7
	Methoxychlor—Kanawha			
None	52.5	52.8	53.0	53.0
0.375	−2.0	−1.5	−3.0	0
0.75	−4.3[2]	0.2	−1.7	−0.8
1.5	−4.5[2]	−4.8[2]	1.2	−1.7
	Methoxychlor—Ames			
None	55.4	53.6	52.7	52.0
0.375	−4.2	−1.2	−1.5	0.2
0.75	−3.0	− .2	1.1	1.5
1.5	−3.4	−0.8	−1.5	0.3
	Dieldrin—Kanawha			
None	52.8	52.5	53.0	52.7
0.375	−2.3	−2.7	−1.5	1.5
0.75	−1.1	−0.5	−1.7	−0.7
1.5	0.9	−4.5[2]	−2.7	1.3
	Dieldrin—Ames			
None	52.6	54.8	50.5	51.3
0.375	−3.2	0.2	0.7	2.5
0.75	−0.6	−2.6	0.7	1.4
1.5	−0.4	−5.4[2]	0.5	1.0

[1] Ounces of technical insecticide per bushel.
[2] Significant at the 5 per cent level.
[3] Significant at the 1 per cent level.

Table 3.—Acre yields of harvested corn of controls (seed not treated and seed treated only with fungicide), and increases or decreases in yield following the use of insecticide seed treatments. Ames and Kanawha, Iowa.—1951.

Insecticide Dosage (oz./bu.[1])	Treated Seed Stored 12 Weeks		Seed Treated Just Before Planting	
	Without Fungicide	With Fungicide	Without Fungicide	With Fungicide
	Lindane—Kanawha			
None	56.3	57.6	56.5	55.5
0.375	−6.0[3]	−2.0	1.6	2.9
2.25	−10.6[3]	−3.3	−3.0	−4.1
1.125	−6.0[3]	−5.0[3]	−0.7	2.9
	Lindane—Ames			
None	93.3	85.3	68.9	72.0
0.5625	−8.3[2]	−0.3	2.9	−0.5
1.125	−13.4[3]	−0.9	3.5	2.6
2.25	−22.8[3]	−9.1[3]	2.1	−0.5
	Aldrin—Kanawha			
None	57.8	56.9	58.4	60.1
0.375	−4.4[2]	2.3	2.9	−0.7
0.75	−3.3	−1.2	−0.8	0
1.5	−4.4[2]	1.1	1.3	0.6
	Aldrin—Ames			
None	78.6	81.8	69.9	70.1
0.375	−3.8	−1.8	−6.2	−4.0
0.75	−3.3	−2.9	0.8	0
1.5	−3.5	−5.9	−1.3	2.7
	Methoxychlor—Kanawha			
None	58.2	59.1	59.2	59.2
0.375	−3.2	−3.4	1.4	2.1
0.75	−4.6[2]	−1.2	−0.3	1.1
1.5	−3.4	−3.5	0.3	0.5
	Methoxychlor—Ames			
None	76.5	81.5	64.3	69.3
0.375	3.4	−0.3	6.9[2]	1.9
0.75	2.2	0.3	6.3	0.3
1.5	2.2	0	3.4	−0.8
	Dieldrin—Kanawha			
None	54.6	56.9	59.1	57.7
0.375	−0.3	−3.4	−2.9	−0.3
0.75	3.2	−2.5	−3.0	2.7
1.5	2.3	−3.3	0.2	2.8
	Dieldrin—Ames			
None	80.5	88.7	61.6	66.1
0.375	−3.1	−6.6[3]	5.3	5.1
0.75	−0.6	−10.5[2]	8.3[2]	8.3[2]
1.5	0.3	−11.6[3]	6.1	4.3

[1] Ounces of technical insecticide per bushel.
[2] Significant at the 5 per cent level.
[3] Significant at the 1 per cent level.

resulted in three significant decreases in stand, but only one in yield, as shown in tables 2 and 3. These decreases were from stored seed without an added fungicide at planting time.

The aldrin treatments resulted in three significant decreases in stand and two in yield from stored seed where no fungicide was used at planting time.

The lindane treatments resulted in eight significant reductions in stand, in stored and freshly treated and an equal number in yield with the stored seed. In six yield cases these reductions in stored seed were highly significant. Also six of these eight yield reductions were with seed not treated with fungicide. Two significant reductions in stand followed the use of freshly treated seed, but these reductions were not reflected in the yields.

Dieldrin appeared to interact with Arasan when the treatment was made twelve weeks prior to planting. This resulted in three significant reductions in yield. However, when the dieldrin and Arasan were applied together just before planting there was an indication of some plant stimulation. In the Ames planting, significant yield increases were realized from freshly prepared dieldrin-treated seed, both with and without the addition of the fungicide.

The following observations were made on the basis of the above work and further preliminary and exploratory experiments in the greenhouse not reported in detail here:

1. Plants from lindane-treated seed corn showed injury to organs even when the seed was germinated in sand immediately after treatment, at the three dosages employed in this investigation.

2. Corn seedlings from lindane treated seed planted in sand, peat, and loam, respectively, showed approximately the same amount of root retardation. However, the retardation of top growth was much more pronounced in sand than it was in either peat or loam.

3. The typical symptoms of lindane injury (shortened, tuberous primary and seminal roots, and short, thick plumules) were not expressed, even after eleven weeks of storage, when the chemical was removed with benzene or chloroform prior to planting.

4. The degree of lindane injury was increased by retarding the rate of germination. Low moisture in the seed, low germination temperatures, and weakening of the seed by mold development in storage, were some of the factors causing increased injury from lindane seed treatments.

5. Injury from insecticide seed treatments caused the seed to be more susceptible to seed-rotting soil pathogens. For this reason less injurious effects of the insecticide treatments were observed when a fungicide was added than when the insecticide was used alone in non-steamed soil. In steamed soil where soil pathogens were not present, the addition of the fungicide did not appear to lessen the injury from the insecticide treatments.

6 In a petri dish experiment, an emulsifiable concentrate of aldrin appeared to nullify the effects of the Arasan treatment, *i e*, a test organism *Pythium* sp, grew unrestrictedly around kernels of corn treated with a combination of aldrin emulsifiable concentrate and Arasan The treated kernels had been placed on water agar inoculated with the test organism On the other hand, Arasan-treated controls, or kernels treated with a combination of aldrin wettable powder and Arasan, restricted the growth of the test organism leaving an uninfected zone of agar around the kernels.

In interpreting the field data if should be realized that these plantings were made in soils which do not normally present an important soil insect problem. Such soils were purposely chosen so that the effects of the chemicals themselves might be more accurately determined Under these conditions favorable results would be complete neutrality of affect of the chemical on the seed This condition was not found with any one of the chemicals used Methoxychlor approached this condition more closely than any of the others; lindane had the most adverse effects on the seed under all conditions; and dieldrin was the most variable under the conditions of the experiments.

Two conclusions stand out from the results presented: (1) Insecticide seed treatments should preferably be made shortly before planting, and (2) a suitable fungicide should be used in combination with the insecticide seed treatment.

House Fly Dispersion Studies in Metropolitan Areas

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Since the dispersion pattern of an insect is of prime consideration in measuring its area of influence in regard to disease transmission and to effective control operations, the advent of radioisotopes as a ready means of marking certain Diptera has focused renewed attention upon the movement of flies in rural and urban areas. Early studies in Miles City, Montana (Parker 1916), indicated that house flies disperse to a maximum distance of approximately 2 miles; however, more than 85 per cent of the recoveries occurred within 1 mile of the release points. Bishopp & Laake (1921), from several tests conducted in agricultural areas near Dallas, Texas, reported movement of *Musca domestica* to distances of 7 to 13 miles. Twelve of the 13 specimens captured within this range were taken between 7 and 11 miles, only one fly being trapped at the 13-mile site. In the initial test, where traps were stationed 0.5, 1, 2, 3, and 4 miles from the liberation point, in excess of 90 per cent of the recaptures were effected within the 0.5 and 1 mile zones. Recently, Lindquist *et al.* (1951), by the use of laboratory-reared specimens tagged with P-32, demonstrated that house flies in rural areas near Corvallis, Oregon, dispersed to distances of 0.5 to 12 miles. In this test also, the majority of the marked specimens were found within 1 mile of the release site.

As part of the research phase of the Poliomyelitis Investigations-Fly Control Program which the Communicable Disease Center is conducting at Phoenix, Arizona, and Charleston, West Virginia, a series of fly dispersion tests was initiated at both cities during the 1951 season. The data reported relate only to the two experiments which were effected at the Phoenix station in June and September 1951.

Description of Study Area.—Metropolitan Phoenix, Arizona,[1] which encompasses an area of 100 to 130 square miles (Fig. 1), has an aggregate population of over 200,000 persons. Approximately one-half of this population resides within the city proper, the remainder being distributed in the adjacent portions of Maricopa County. The community lies upon the broad, flat floor of the Salt River valley, the dry river bed forming the southern edge of the metropolitan area. On the basis of socio-sanitational levels, the city itself can be classified into business (Fig. 1, H) and several types of residential sections (A through F). Although Sections E and F definitely represent a lower level of residency than Sections A to D, the degree of sanitation in these two sections surpasses that manifested in the county zone lying between the city limits and the Salt River. Composed of approximately 270 blocks of primarily Latin-American habitations, this county zone is characterized by an abundance of animal pens and privies which, with the absence of any organized refuse collection system, makes it a source of prodigious fly production. In addition, meat packing concerns and municipal garbage disposal sites on the edge of the Salt River contribute heavily to the resident fly populations.

As an aid to extensive dispersion studies, the Phoenix area is favored by relatively uniform weather conditions, an extended fly season (10 to 12 months) and a fly potential of enormous magnitude. Although blowflies are present in varying numbers throughout the year, the predominant, and problem, species is *Musca domestica.*

Collection, Marking, and Release of Flies.—Essentially, the test procedures involved removing a portion of the normal fly population at the release site, marking these specimens with radioisotopes, liberating the tagged flies at the point of original capture, and then recovering as many radioactive flies as possible by means of baited traps distributed in a definite design at varying distances from the release point.

To eliminate the factor of induced population pressure, all specimens to be marked were collected from the resident

[1] The term "metropolitan" is subject to several interpretations. For the purpose of this discussion, arbitrary limits have been designated as indicated in Figure 1.

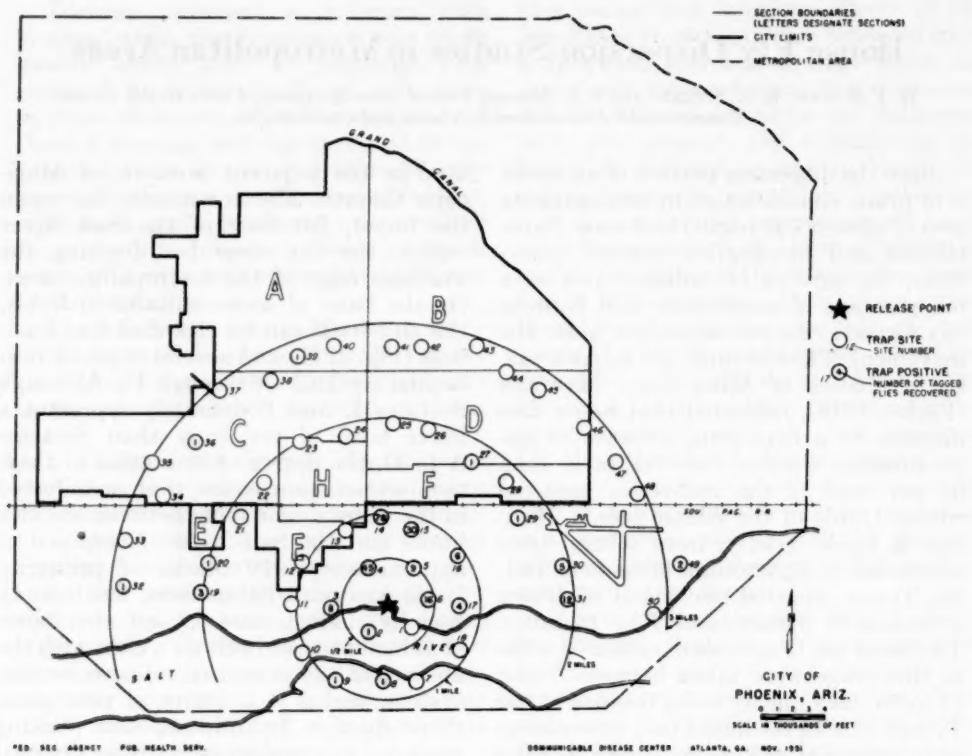

FIG. 1.—Map of Phoenix, Arizona, showing dispersion pattern in June 1951 test.

fly population at the predetermined release site.[1] For this purpose, cone net (Maier & Dow, 1949) and fly trap techniques were employed for a 1 or 2 day period prior to the feeding operation. Approximately 1000 to 4000 captured specimens were placed in each of 24 holding cages. A dilute, honey-water solution sustained these specimens until the introduction of the radioactive milk (Jensen & Fay, 1951). The latter was prepared by adding 1 millicurie of P-32 as phosphoric acid to 1 liter of milk (evaportated milk, honey and water). Small salve tins containing cellucotton or squares of plastic screening served as feeding stations, two to four stations per cage.

The radioactive milk was offered to the flies for periods of 23 and 12 hours respectively in the two tests, replenishment of the supply being made as often as required. Servicing of the feeding stations was accomplished by a gravitational flow technique (Fig. 2). By insertion of a glass pipette through a slit in a small sponge rubber square fastened to one side of the cage, radioactive milk passed directly from the supply bottle to the feeding station. Rate of flow was regulated by a pinchcock on the rubber tubing connecting the pipette to the supply bottle. This method minimized the possibilities of contamination and prevented the accidental escape of marked flies. Two liters of milk was used in each test.

To obtain a definite base line for measuring the rapidity of dispersion, the release of tagged flies was purposely scheduled at twilight on the same day on which they were fed. Since the liberated specimens immediately sought nearby night resting surfaces, the initial fly dispersion could then be considered as beginning at dawn of the following day.

Approximately 31,000 and 56,000 house flies constituted the June and September releases, respectively. The best method of determining the number of flies liberated was to mark a 5 inch square on the

[1] Quarterman, K. D., W. Mathis, and J. W. Kilpatrick. (Unpublished manuscript) "Fly Dispersion in Urban Areas of Southern United States." Communicable Disease Center, Savannah, Georgia.

side of each 18 inch square cage and relate the fly counts within that square to the total cage population. "Estimated" versus actual population tests showed that the average of three fly counts within the 5 inch square times the factor 60 yielded density values within an error of 7.5 per cent. *Musca domestica* comprised more than 95 per cent of the specimens released.[1]

In the June test, a meat packing plant located at the edge of the Salt River served as the release point. This site is a continual source of copious fly breeding and abundant fly attractants. North, east, and west of this location extend one to two miles of substandard residential area while immediately south the terrain consists of the essentially dry, barren, Salt River bottom, approximately one mile in width. For the second test, the site which represented the focal point of fly movement in the June study was chosen as the release station. In the center of a substandard residential area, this location is bordered on the southern half by residential zones of similar composition. Within one mile to the north, however, lie the business and the better class residential sections of Phoenix.

RECAPTURE METHODS AND DETECTION OF MARKED FLIES.—For recapture of marked flies, the attached-bait-pan type of fly trap[2] was utilized in both tests. One-quarter pint of chicken entrails served as the bait, each trap being rebaited on alternate days with fresh material. Traps remained in continuous operation for 15 days with the exception of one at the release point which operated for one hour each day. Daily removal of trap contents usually occurred during the first 6 to 8 day period, subsequent servicing being scheduled on a 2 to 3 day basis. At the time of collection, the flies were killed with chloroform and placed in ice cream cartons.

In the June test, 50 traps were distributed in concentric rings, 6 traps at the 0.5 mile distance, 12 at 1 mile, 13 at 2 miles, and 19 traps at 3 miles (Fig. 1). At the 0.5 and 1 mile distances the rings were complete, but at the farther distances the trap stations were confined to the area north of the Salt River. To insure a more "equal" chance of recapture at all distances, the circumferential interval between successive traps on the same ring was maintained at 0.5 mile. In selecting the individual trap site, consideration was given to the over-all fly attractivity of the general area, provided the block chosen remained within one-eighth mile of the theoretical site originally selected by means of compass designations.

In the September study, traps were located at 4 and 5 miles as well as at the distances utilized in the earlier test. However, instead of designating sites on narrow concentric rings emanating from the release point, distance bands of 0.5 mile width were established (Fig. 2). Thus, any trap situated on the 1 mile band could be between 0.75 and 1.25 miles from the release point. No attempt was made to maintain a uniform interval between successive traps, the chief criterion for trap location being the selection of the most fly attractive areas in each of the distance bands. Of the 50 traps in operation beyond the release site, 6 were at 0.5 mile, 12 at 1 mile, 11 at 2 miles, 9 at 3 miles, 8 at 4 miles, and 4 at 5 miles.

To detect the tagged flies, all trap collections were processed by a count rate meter equipped with a Geiger tube having a mica end window with a thickness of 3.2 milligrams per square centimeter. A specimen yielding consistent counts above background was considered as a "tagged" fly. The usual count rate for the radioactive specimens varied between 200 and 5000 counts per minute. In each sample, the marked as well as the unmarked flies were determined to genus and species.

RESULTS JUNE TEST.—The data for this test (Table 1, Fig. 1) reveal that *Musca domestica* dispersed readily throughout the area, tagged specimens being captured on all rings. As might be anticipated, the percentage of positive collections per ring varied inversely with the distance from the release point. However, contrary to expectation, more radioactive flies were taken on the 1 mile circle than on the 0.5 mile ring. Approximately 88 per cent of the 227 specimens recovered were trapped within one mile of release point.

With regard to the rapidity of movement, limited dispersion up to one mile occurred within 24 hours after release,

[1] Sample checks revealed that in excess of 95 per cent of these flies were radioactive.

[2] A small trap (height 12½", diameter 6") attached to a metal standard (28" high), suitable for use at or above ground level.

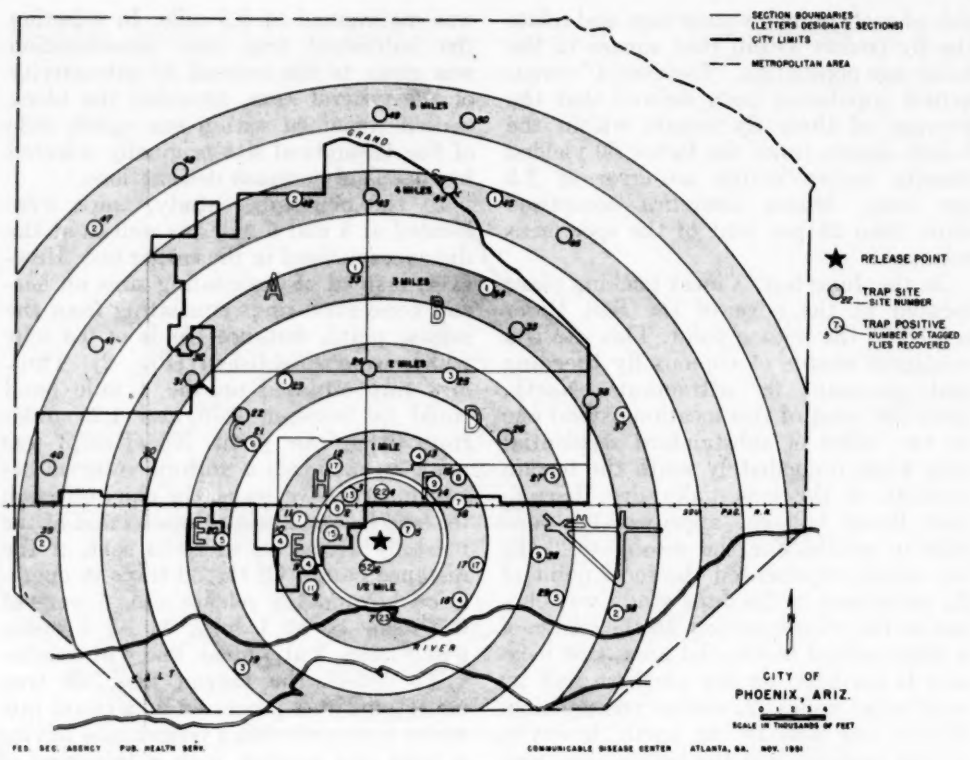

FIG. 2.—Map of Phoenix showing the dispersion pattern in the September 1951 test.

movement to the 2 and 3 mile rings being manifest within 48 hours. Maximum recovery of marked flies took place on the third day after release, a gradual decline being evident in subsequent collections. The abrupt rise in positive collections and number of tagged specimens recovered on the second day after release indicated considerable movement during the time interval between the first and second collection period (18 to 42 hours after release). At the release site, the 1 hour collections yielded 101, 80, 22, 23, 15, and 14 marked flies, respectively, on the first 6 days following liberation. Three subsequent collections on the 7th, 9th, and 15th days after release were negative, indicating possible mortality of the tagged specimens, dispersion, or elimination of the P-32 from the insect's body.

The most significant finding in this test concerned the preferential movement of marked flies into certain portions of the metropolitan area. As shown in table 2, more than 77 per cent of the total tagged flies recovered were taken at 7 of the 50 trap sites. Particularly outstanding was the capture of 108 of the 120 flies collected on the 1 mile ring from two adjacent stations (Fig. 1, sites 14 and 15). The recoveries at these two locations accounted for the greater number of marked flies being found in the 1 mile than in the 0.5 mile zone. These data are contrary to any assumption of random dispersion of the mass population from a given point to peripheral sites. Instead, it appears that certain areas possess a higher degree of fly attractivity which in turn results in greater fly movement towards such environs.

Analysis of the data for the total number of untagged flies collected at each trap station reveals that the preferential movement towards particular sites was associated with the attractivity of these sites to house flies. With one exception, those locations which were characterized by substantial house fly populations likewise produced the majority of the marked flies. Animal pens apparently provided the conditions which caused the preponderance of house flies at these points. No apparent correlation existed between the

dispersion pattern and the weather factors of temperature, rainfall, humidity, and wind. During the period June 23 to 30, maximum temperatures averaged 105° F.; wind velocity, 4.9 miles per hour; and minimum relative humidity, 14 per cent.

RESULTS SEPTEMBER TESTS.—Data (Table 3) disclose dispersion of *Musca domestica* throughout the area and up to distances of 4 and 5 miles. Maximum recoveries again occurred within the 0.5 and 1 mile bands, more than 50 per cent of the collections in both zones being positive. Within 48 hours after release, tagged flies were taken in all but one of the 18 stations in the 0.5 and 1 mile zones. The trend in the movement of the marked specimens from the release site was clearly demonstrated by the general increase in the number of positive sites and of radioactive flies retrieved during the first three post-release days. The limited recoveries, which occurred within the 0.5 and 1 mile bands on the first day, were followed by maximum captures in these two zones on the second day.[1] At the same time, tagged flies began to appear in the outer zones; 6 of the 11 stations on the 2 mile band, 1 of 9 stations on the 3 mile band, and 2 of the 8 sites on the 4 mile band yielding positive collections on second and third post-release days. At the conclusion of the test, marked specimens had been collected from all sites on the 0.5 and 1 mile bands while the percentage of positive stations per band at the 2, 3, 4, and 5 mile distances ran 72, 44, 37, and 25 respectively.

As in the June release, the number of positive collections per band decreased with the distance from the liberation point. In contrast to the initial test, approximately the same number of tagged flies was recaptured in the 0.5 and 1 mile zones (Table 3). Again more than 80 per cent of the marked flies retrapped came from collections in these zones. Beyond the one mile limit and particularly in the 3, 4, and 5 mile bands, recovery of tagged specimens dropped markedly. A similar precipitous decline in the number of specimens captured in the 3 mile band was also revealed in the June test (Table 1). While this significant reduction can to a large degree be ascribed to the greater distance involved, consideration must also be given to the fact that as the radial distance increases, the number of radioactive flies per unit area greatly diminishes, so that the chances of capturing marked flies in the outer rings are materially decreased.

Pronounced preferential movement toward a few selected sites was far less manifest in the September test than in the June release. This was expected since the sites for the second study were chosen on the basis of "equal" fly attractivity. That stations more favorable to *Musca domestica* concentrations were chosen for the second study is clearly illustrated by two collations: (a) the percentage of *Musca domestica* in the total flies collected in the spring and fall tests averaged 65.8 and 87.7 respectively, and (b) the percentage of collections containing 95 per cent house flies ran 15.6 and 40.0 respectively for the first and second releases. The total number of flies trapped in the fall experiment amounted to 808,072 specimens, almost 3 times the quantity collected in June. While the higher densities which prevailed in September probably caused part of this decided increase in the quantities of flies trapped, the selection of trap sites more attractive to *Musca domestica* was also an important factor underlying the augmentation.

As the map (Fig. 2) discloses, flies from the release point penetrated to the business and residential portions of the city. Of particular significance from the standpoint of potential disease transmission, were the captures of 13 and 17 tagged flies respectively at stations 3 and 12. With the release point situated in the middle of a substandard residential area characterized by unsanitary privies and exposed human excreta, fly movement into the city could easily serve as transmission vehicle for pathogens available at these sources. Further, since site 13 is one of the two adjacent blocks utilized as a city market, the chances of potential food contamination are obvious.

In the September test, weather factors again appeared to have little effect upon the dispersion pattern. During the period September 26 to October 3, maximum temperatures averaged 93° F., wind velocity 4.6 miles per hour, and minimum relative humidity 31 per cent.

DISCUSSION.—In the June study, the

[1] The numbers of tagged flies recovered each collection period at the 0.5, 1 and 2 mile bands fluctuated in direct relation to the total quantities of flies trapped during these periods.

selection of a highly fly attractive release site located between a river bottom devoid of attractants and an extensive residential section containing numerous attrahents made it possible to determine the influence of such attractivity upon fly movement. As the results revealed, *Musca domestica* migrated readily from the release site with definite preferential movement toward certain trap stations, particularly those established on the 0.5 and 1 mile rings north of the point of liberation. Of the seven sites either in the river bed or on the opposite edge, three proved positive but yielded only three marked flies. In contrast, eight of 11 sites on the 0.5 and 1 mile rings north of the river bed contributed a total of 196 tagged flies, thus demonstrating that major fly dispersion emanated towards the residential areas which apparently provided conditions more suitable for feeding and reproduction than those existing in the dry river bottom.

Proceeding on the previous evidence that fly movement is governed by the fly attractivity of an area, it naturally follows that in a random selection of trap stations, as stipulated in the June test, certain locations normally would possess a greater abundance of house fly attrahents than other stations. The preponderance of marked house flies taken in stations 4, 14, and 15 validate this assumption, these sites furnishing more than 76 per cent of the radioactive flies captured at the 0.5 and 1 mile distance. The same three stations also provided in excess of 60 per cent of the total flies captured in the two zones, 21 of the 25 trap samples containing over 95 per cent house flies.

The recovery of the greatest number of radioactive flies at the 1 mile zone conflicts with the preconception that maximum catches would occur at those stations nearest the release point. In previous studies (Lindquist *et al.* 1951, Bishopp & Laake 1921, and Parker 1916), the capture of more flies at sites closer to the release point was favored by stationing proportionally fewer traps per circumferential zone on the outer distance rings. In the June test, this inequality was overcome by locating the traps at uniform intervals on each distance ring, thereby creating an equal chance of recovery, whichever ring the flies crossed. Under such conditions it was anticipated that, regardless of the directional trend of dispersion, the traps at 0.5 mile would furnish the predominant catch. To explain the seemingly paradoxical data, consideration must be given to the house fly attractive values of the two sites, 4 and 14. By using a comparison of the total *Musca domestica* taken at the two sites as the criterion, it can be assumed that site 14 in yielding 53,628 flies possessed a higher level of attractivity than site 4 with only 7497 specimens. Thus, the greater recovery of tagged flies at site 14 appears to be due, in large part, to that area having a higher degree of attractivity for *Musca domestica.* Two interrelated factors, distance and area attractivity, apparently governed the dispersion pattern. As Parker (1916) points out, the various inciting and inhibiting agents influencing dispersion fluctuate in intensity and duration and frequently exert compensatory responses in the fly. In this instance, the presence of an attractive force of "maximum" intensity at a site 1 mile from the release point presumably invoked greater stimulatory response from the released population than did the location possessing an "average" attractive force 0.5 mile distant.

Based on the foregoing findings of the June test, the September experiment was outlined to determine:

(a) If the general pattern of dispersion as presented by the June test could be altered by selecting the trap stations primarily on the basis of each site possessing an "equal" attractivity for house flies and without regard to the maintenance of equidistant intervals between adjacent stations on the same band.
(b) Whether there was any significant counter movement of house flies between the point of maximum recovery (Station 14) and the release site for the June test.
(c) The amount of infiltration into the city from an adjoining substandard area of high fly potential and attractivity.

The data for the September test (Table 3) strengthen the premise that area attractivity is a major factor in governing house fly dispersion. By "equalizing" the attractive values of the respective sites in the September study, the percentages of trap collections and the number of tagged flies recovered per zone were increased markedly over those obtained for the June release. Of the 441 collections on the June test, only 12.9 per cent were positive with 17 of the 31 trap stations (51.4 per cent) in the 0.5 to 2 mile zones

Table 1.—Number of positive collections and tagged house flies per zone—June 1951 test.

DATE OF COLLECTION	0.5 MILE			1 MILE			2 MILE			3 MILE			NO. OF POSITIVE COLL'S. PER DAY	NO. OF POSITIVE FLIES PER DAY
	No. Coll.	No. Coll's. Pos.	No. Pos. Flies	No. Coll.	No. Coll's. Pos.	No. Pos. Flies	No. Coll.	No. Coll's. Pos.	No. Pos. Flies	No. Coll.	No. Coll's. Pos.	No. Pos. Flies		
6-24	6	1	6	12	1	6	13	0	0	19	0	0	2	12
6-25	6	4	16	12	4	27	13	3	6	19	2	2	13	51
6-26	6	4	31	12	4	43	13	4	7	19	0	0	12	81
6-27	6	2	9	12	3	20	13	2	2	19	1	1	8	32
6-28	6	3	8	12	2	6	12	2	4	18	1	1	8	19
6-29	6	2	8	12	3	12	12	1	12	19	0	0	6	22
7-2	6	1	1	11	3	3	13	1	2	19	0	0	5	6
7-5	4	0	0	12	2	3	13	0	0	19	1	1	3	4
7-9	6	0	0	10	0	0	13	0	0	18	0	0	0	0
Total	52	17	79	105	22	120	115	13	23	169	5	5	57	227
Per cent of Zonal Collections Positive		32.7			21.0			11.3			3.0			
Per cent Positive Flies per Zone		34.8			52.8			10.1			2.2			

yielding radioactive specimens. In the September release, 28.4 per cent of the 447 collections were positive with 26 of the 29 stations (89.6 per cent) in the 0.5 to 2 mile zones providing tagged flies. Thus it is apparent that placement of traps at sites of "equal" fly attractivity resulted in a more even distribution of the tagged fly recovery than occurred when prime consideration was given to the maintenance of equidistant intervals between adjoining traps.

Further, the positive collections at all stations on the 0.5 and 1 mile bands in the September test indicate that when the trapping stations possess an "equal" attractivity value, fly movement is shown to occur in all directions. Under these conditions, a random type of fly migration appears in the dispersion pattern. In the June test, this tendency towards random migration was apparently counteracted by the predominance of fly attractive sites in the area north of the river bed, a situation which favored major fly movement towards the city.

The dominant recoveries at sites 4 and 14 (Fig. 1) and sites 6 and 7 (Fig. 3) reveal considerable fly movement between the liberation points of the two tests. Apparently a chain of attractants in this general area provides a "favored" path of dispersion. Since fly movement between these two locations prevails, the question arises as to whether flies dispersing from one point may not eventually return to the site of origin. Conceivably, the fly upon reaching any attractive site does not necessarily remain there but may again disperse in a randomized manner. To prove or disprove the occurrence of such reciprocal migration, however, further tests are required in which tagged flies trapped at certain stations will be remarked and released for subsequent recapture. Of significance from the present data is the fact that house flies move into, as well as away from, a source of high fly production such as site 7 (Fig. 3).

From the practical aspects of fly control, the reported data show that house flies disperse rapidly and in numbers to distances of 0.5 and 1 mile, a finding which substantiates and extends similar evidence reported by Parker (1916), Bishopp & Laake (1921), and Lindquist (1951). The fact that more than 80 per cent of the tagged flies were captured within 1 mile of the release sites definitely shows this distance to encompass the area of maximum dispersal. While this furnishes a specific guide in delimiting the area of control operations, it does not necessarily mean that a 1 mile limit should be arbitrarily established around all communities employing control measures. Such a procedure could be expensive and entirely unwarranted. The designation of the control boundary should be preceded

Table 2.—Percentage of tagged flies recovered at sites predominant for *Musca domestica* June 1951.

DISTANCE (MILES)	TAGGED FLIES RECOVERED (All Sites)	*M. domestica* PREDOMINANT SITES	
		Tagged Flies Recovered	Per Cent Tagged Flies Recovered
0.5	79	45 (Site 4)	57.0
1.0	120	108 (Sites 14, 15)	90.0
2.0	23	20 (Sites 19, 30, 31)	87.0
3.0	5	2 (Site 49)	40.0
	227	175	77.1

Table 3.—Number of positive collections and tagged house flies per zone—September 1951 test.

Date of Collection	0.5 Mile			1.0 Mile			2.0 Miles			3.0 Miles			4.0 Miles			5.0 Miles				
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	D	E
9-26	6	2	8	12	1	1	11	0	0	9	0	0	8	0	0	4	0	0	3	9
9-27	6	5	25	11	11	25	11	3	7	9	1	1	8	0	0	4	0	0	20	58
9-28	6	5	10	12	7	14	11	5	8	9	0	0	9	2	2	4	0	0	19	34
10-1	5	5	46	11	9	30	11	6	8	9	3	3	8	2	3	4	1	1	26	91
10-2	6	2	7	12	6	9	11	5	7	9	2	2	8	0	0	4	0	0	15	25
10-3	6	4	4	12	8	13	11	3	4	9	1	1	8	0	0	4	0	0	16	22
10-4	6	3	4	12	3	6	11	0	0	9	0	0	8	0	0	4	0	0	6	10
10-5	6	3	4	12	5	7	11	1	1	9	1	1	8	0	0	4	0	0	10	13
10-8	6	3	9	12	6	10	11	2	2	9	0	0	8	0	0	4	1	1	12	22
Total	53	32	117	106	56	115	99	25	37	81	8	8	72	4	5	36	2	2	127	284
Per cent of zonal collections positive	60.4			52.8			25.3			9.9			5.6			5.6				
Per cent Positive flies per zone	41.2			40.5			13.0			2.8			1.8			0.7				

A. Number of Collections
B. Number of Collections Positive
C. Number of Flies positive
D. Number of Positive Collections per day
E. Number of positive flies per day

by an adequate appraisal of the fly breeding and fly attractants in the peripheral areas bordering the community. Where sufficient attractive sites are interspersed between the community and the 1 mile limit, and the expanse beyond this limit possesses a relatively low value of fly attractiveness, the designation of the 1 mile boundary is probably justified. However, consideration must be given to normal radial dispersion of flies from a given site. Thus, although a high percentage of marked flies in the June test moved from the meat packing plant to an area adjacent to the city limits (sites 14 and 15, Fig. 1), the data show that in the September test (Fig. 2), 46 per cent of the flies retrieved (within 1 mile) from the tagged population liberated in this same area moved *away from, not toward,* the community. Further emphasis can be assigned to this 46 per cent recovery rate since it derived from only 5 sites as compared to the remaining 54 per cent which related to 13 sites located inside the city. Therefore, as a general rule, to minimize fly infiltration into the city from the county areas, those environs within 0.5 mile of the city should receive primary attention since they not only provide fly breeding sources but also furnish stimuli which attract fly migrants from sources beyond the 0.5 mile distance.

With the radial movement of flies from an area being channeled by the attractivity value of the surrounding environs, it seems evident that, under certain conditions, acceptable fly control can be achieved in residential developments with good sanitation even though they lie in close proximity to problem sites. Field observations have noted that some residential sections receive a minimum of fly infiltration from nearby problem sites while in other instances the reverse is true. Under the latter circumstances, the differential in attractivity levels between the areas on opposite sides of the problem sites apparently favors migration into the city whereas with the former, the dominant dispersion of flies is away from the community.

Although control programs consistently stress the removal of breeding sources, the elimination of fly attractants has received only secondary attention. It is obvious that unless such attrahents are disposed of, successful control in communities surrounded by external fly production sources is impossible because of infiltration of flies from adjacent areas. Despite reduction of fly breeding media in Sections E and F of Phoenix to a minimum level, relatively high fly prevalences frequently occur solely because of the affinity exhibited by the extraurban flies for attractants (dishwater, fruit, animal excrement) still available within the city.

With reference to dispersion beyond 1 mile, there was definite evidence of fly movement up to the 2-mile range, particularly in the September test. Consequently, extension of control limits from 1 to 2 miles may, in some circumstances, be desirable. Radioactive flies also migrated to the 3, 4 and 5 mile zones, but the numbers of specimens collected at

those distances were too small to warrant emphasis at this time. Admittedly, because of the pronounced dilution of the released population per unit area at the more distant ranges, the small recoveries may possess far greater value than has been assigned to them. However, in view of the general popular tendency to cite and to apply without qualification such isolated maxima of fly dispersion, a conservative interpretation at present appears justified. Likewise warranted is the caution that the findings relate specifically to the area of study; therefore, generalizations on fly dispersion per se without consideration of the qualifying circumstances may be quite misleading. As Parker (1916) noted, the movement of flies represents a complex interaction of numerous stimuli, both environmental and within the insect itself. To resolve these factors into a workable control principle is a challenge to the entomologist.

SUMMARY.—Releases of 31,000 and 56,000 house flies tagged with radioactive phosphorus at Phoenix, Arizona, in June and September 1951 reveal that the principal zone of dispersion is within 1 mile of the release point. Of the 227 and 284 marked specimens collected from baited traps distributed over the metropolitan area, 88 and 81 per cent respectively were found within the 1 mile zone.

The percentage of positive recoveries per band varied inversely with the distance from the release. Movement of flies occurred rapidly. Specimens were found within 24 hours at 0.5 and 1 mile, the wave of dispersion spreading to 2 and 3 miles within 48 hours and to 4 miles within 72 hours.

Although tagged flies were collected 3, 4 and 5 miles from the release points, the number of specimens taken at this distances were too few to warrant emphasis at the present time, However, the 13 per cent recovery on the 2 mile band in the September release indicates that movement to this distance may be of significance.

The major factor governing the dispersion pattern was the attractivity of the area for house flies. In the June tests where trap sites were chosen primarily on a design basis, seven stations furnished 77 per cent of the tagged flies, these sites being characterized by high fly populations, predominantly *Musca domestica*. Of the 12 stations on the 1-mile ring, two adjacent sites provided 90 per cent of the 120 marked flies retaken and more than 62 per cent of the total flies trapped. Selection of trap stations on the basis of "equal" fly attractivity values in the September test produced a more uniform rate and pattern of dispersion than in the June release. Data indicate that if attractant stimuli of "equal" intensity surround a given point, dispersion can follow a random design. Where the attractivity values are unequal, this radial dispersion movement is channeled along the paths of greater fly attractivity which emanate from the release site.

The importance of any problem site of high fly production located one or more miles from a community is dependent upon the degree and extent of fly attractivity in the area intervening between the city and the site. Although an intervening area more conducive to fly dispersion favors movement towards the city, the apparent reciprocal migration of flies between attractive sites located within the intermediate zone may dissipate to a large degree the ultimate effect of such infiltration upon a control program within the city.

In view of the influence of attractants upon the infiltration of house flies into an area, removal of these substances is of parallel importance to the elimination of fly breeding media on any community fly control program.

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Control of the American Grasshopper with Organic Insecticides in Florida[1]

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During the summer and fall of 1950 damage to cultivated crops by the American grasshopper, *Schistocerca americana* (Drury), was reported from several areas in southeastern United States. This grasshopper has long been present throughout most of the Southeast, but rarely in injurious numbers. Occasional reports of damage have usually been restricted to part of a farm or field. In 1950, however, severe damage was general enough to warrant investigations on the control of this species. Therefore, during the 1951 season tests were undertaken to provide information on the effectiveness against *S. americana* of some of the new insecticides, especially of aldrin, chlordane, and toxaphene, which had been recommended for the control of grasshoppers in the West (Wakeland & Parker 1951).

The western half of Alachua County, Florida, was chosen for the tests as a severe infestation had been reported in this area in 1950 and a large number of overwintered adults were present in the spring of 1951. These adults began ovipositing about the middle of March. The last oviposition was observed on May 7. Hatching began the latter part of April and continued through the middle of June.

In addition to *Schistocerca americana*, 10 other species of grasshoppers were collected on the test plots, the most numerous being *Melanoplus femurrubrum propinquus* Scudd. There were also large numbers of a tettigoniid, *Conocephalus* sp.

The tests were conducted from May 3 to June 13 on small plots (0.1 acre) with hand equipment and on large plots (0.4–1 acre) and in the field (8 and 16 acres) with power equipment. All nymphal instars of *Schistocerca americana*, as well as nymphs and adults of the other species, were present. Aldrin, toxaphene, chlordane, parathion, and lindane were applied as dusts and dieldrin, aldrin, and heptachlor as emulsion sprays. Several series of treatments were made with different materials at different dosages. Com-

[1] Florida Agricultural Experiment Station Journal Series No. 68. The investigations herein reported were conducted as a cooperative project of the Florida Agricultural Experiment Station and the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Table 1.—Effectiveness against the american grasshopper of some organic insecticides applied with hand equipment in small-plot tests.

Material	Active Ingredient per Acre	Per Cent Mortality (Four Replicates)			
		After 3 Days		After 5 Days	
		Range	Average	Range	Average
Dusts:					
Aldrin 2.5%	4.4 oz.	93– 98	95	84– 98	91
	9.6 oz.	99–100	99	98– 99	99
	10.4 oz.	86– 99	94	96–100	98
Parathion 2%	6.24 oz.	91– 96	94	85– 94	91
	9.6 oz.	98–100	99	87– 99	96
Parathion 1%	3.1 oz.	81– 90	86	67– 77	73
Toxaphene 10%	2.55 lbs.	86– 98	91	88– 97	88
	3.45 lbs.	96– 99	98	95–100	98
Chlordane 5%	1.30 lbs.	89– 97	94	86– 98	93
	1.42 lbs.	31– 94	70	28– 78	65
Lindane 3%	12.5 oz.	64– 98[1]	83[1]	58– 93[1]	81[1]
Sprays (Emulsifiable Concentrate):					
Aldrin 23%	5 oz.	98–100	99	98–100	99
Dieldrin 18.5%	1.5 oz.	94– 99	96	91– 98	95
Heptachlor 48%	4 oz.	96– 98	96	95– 99	97

[1] 8 replicates.

mercially prepared materials were used in all tests, but all dosages were determined as the amount of active ingredient per acre.

Estimates of the populations before and after treatment were made by sweeping the plots with an insect net. On all plots of less than an acre 20 sweeps were made per plot, whereas 30 sweeps were made per plot of 8 and 16 acres. The per cent mortality due to the treatments was calculated by the formula

$$100\left(1-\frac{Ta\times Cb}{Tb\times Ca}\right).$$

Here *Tb* equals the total number of grasshoppers swept from the plot before treatment, *Ta* the total swept after treatment, *Cb* the total swept from the check plot before treatment, and *Ca* the total swept from the check plot after treatment.

Nymphs of *Schistocerca americana* tend to congregate close to the place where they hatched for several days to several weeks before spreading out over the general area. Consequently, as many as 53 newly hatched nymphs were sometimes caught in a single sweep during posttreatment counts. When it was certain that these nymphs could not have been present in time to be affected by the insecticide, they were excluded from the totals used for evaluating control.

SMALL-PLOT TESTS.—The small-plot tests were conducted in a field of year-old, dense, green hairy indigo located on the Florida Agricultural Experiment Station Farm at Gainesville. Each plot was 66 by 66 feet and contained 0.1 acre. All treatments were replicated four times and one check plot was included with each replication. The dusts were applied with two crank-type hand dusters and the sprays with a 3-gallon pneumatic-type hand sprayer. The dusters were filled and weighed and after each application were reweighed to determine the amount of dust applied. For the sprays it was found that 3 gallons of water were required to give uniform coverage of a 0.1-acre plot. The required amount of emulsion concentrate to give the desired dosage was added to water to give this amount of spray and the emulsion was applied at a pressure of 30 to 40 pounds per square inch. In the application of both the sprays and dusts 10 round trips were made per plot with a swath width of approximately 3.5 feet. All treatments were made early in the morning when the air was quiet, thereby minimizing the danger of drifting. Sweeps were generally made the day before and 3 and 5 days after treatment. Results from these treatments are given in table 1.

All the materials except the lindane and the 1 per cent parathion dusts gave satisfactory control. The chlordane used in one test had been in an opened bag since 1949, while that used in another was purchased in 1951. The poorer control obtained from the older material indicated that it had lost considerable toxicity. The mortalities secured from the fresh material were in line with those expected from this insecticide when used in grasshopper control.

In the first tests aldrin dust was used at higher dosages, 9.6 and 10.4 ounces per acre, than that recommended for grasshopper control in other areas (Wakeland and Parker 1951). In later tests the amount was reduced to conform more closely to the recommended dosage of 3 ounces per acre. The average amount applied per replicate in these tests was 4.4 ounces, which was as close to 3 ounces as could be obtained with the equipment and plot size used. Mortalities obtained in 3 and 5 days were high.

Toxaphene gave good control at 2.5 pounds per acre, but mortalities were higher when the dosage was increased to 3.5 pounds per acre.

Numerous reports of early season damage to tobacco by grasshoppers had been received, but because of objectionable residues aldrin, chlordane, and toxaphene could not be recommended on that crop. Since parathion had already been recommended for the control of some of the other insects attacking tobacco, it was included in the tests to determine its possible effectiveness against grasshopper infestations in tobacco fields. As shown in table 1, the 2-per cent parathion dust used at 6.2 ounces per acre gave excellent control.

LARGE-PLOT TESTS.—The large-plot tests were conducted on private land and on the experiment station farm. The plots ranged from 0.4 to 1 acre. The first series of tests was applied to an abandoned year-old tobacco field near Alachua, Fla. As the season progressed it became apparent that the field of hairy indigo in

which the small-plot tests were conducted contained as many grasshoppers as any place in the county. Because of the convenience of using land located on the experiment station farm the remaining series of large-plot tests were also carried on in this field. All materials were applied as emulsion sprays.

Four series of tests were conducted with a low gallonage row-crop sprayer mounted on a 1-ton truck. This sprayer operated at a pressure of 40 pounds per square inch and was calibrated to apply 5 gallons per acre. The spray boom with 18 nozzles covered a swath of 18.5 feet. Materials were applied at various times during the day. All treatments were replicated three times and an untreated plot was included. Sweeps of the plots were made 1 or 2 days before and 3 and 5 days after treatment. Results of these tests are given in table 2.

All materials except lindane concentrate gave satisfactory results. Dieldrin at 1.5 ounces, heptachlor and aldrin at 2 ounces, toxaphene at 1.5 pounds, and chlordane at 1 pound per acre gave exceptionally good control 3 or 5 days after treatment.

FIELD TESTS.—In one experiment insecticides were applied to an abandoned pasture near Newberry, Fla., with the row-crop sprayer just described and with a jeep-mounted sprayer having an oscillating boom blower mounted at the rear. The blower sprayer operated at a pressure of 40 pounds per square inch and was calibrated to apply 2 gallons per acre. The width of the swath covered by this machine was 40 feet. The dieldrin was applied with the jeep sprayer to approximately 16 acres of the abandoned pasture, while the aldrin and toxaphene were applied with the row-crop sprayer to approximately 8 acres each. The treatments were made in the same field and were not replicated. An untreated plot of approximately 4 acres was left at one end of the field. Sweeps of the plots were made 3 days before and after treatment. The data for these experiments are given in table 3.

Table 3.—Effectiveness against the american grasshopper of some organic insecticides

MATERIAL (EMULSIFIABLE CONCENTRATE)	ACTIVE INGREDIENT PER ACRE	PER CENT MORTALITY AFTER 3 DAYS
Dieldrin 18.5%	1.5 oz.	97
Aldrin 23%	2 oz.	95
Toxaphene 60%	1.5 lbs.	95

Apparently, one machine was as satisfactory as the other, and the three treatments were equally effective. This field was revisited approximately 3 weeks after the treatment and all sprayed areas were still free of grasshoppers. It was possible at that time to distinguish between the untreated plot and the adjacent treated plot within a few feet by the presence or absence of grasshoppers.

The types of equipment used in these

Table 2.—Effectiveness against the american grasshopper of some organic insecticides applied with a row-crop sprayer in large-plot tests.

MATERIAL (EMULSIFIABLE CONCENTRATE)	ACTIVE INGREDIENT PER ACRE	PER CENT MORTALITY (THREE REPLICATES)			
		After 3 Days		After 5 Days	
		Range	Average	Range	Average
		0.4 Acre Plots			
Aldrin 23%	4 oz.	96– 98	97	98–100	99
Toxaphene 60%	1.5 lbs.	97– 98	97	94– 99	97
Lindane 20%	8 oz.	73– 86	80	62– 91	76
		0.5 Acre Plots			
Dieldrin 18.5%	1.5 oz.	95–100	98	95– 98	97
Heptachlor 24%	2 oz.	92– 95	94	92– 98	96
Chlordane 72%	1 lb.	87– 98	94	94– 96	95
Toxaphene 60%	1.5 lbs.	86– 95	91	79– 99	91
Aldrin 23%	2 oz.	80– 98	89	84– 95	91
		0.8 Acre Plots			
Dieldrin 18.5%	1.5 oz.	98–100	99	97– 99	98
Aldrin 23%	2 oz.	97– 98	98	96– 98	97
		1.0 Acre Plots			
Toxaphene 60%	1.5 lbs.	97– 98	98	93– 97	96
Chlordane 72%	1 lb.	87–100	94	95– 98	96
Aldrin 23%	2 oz.	94– 98	96	84– 94	91

experiments all gave satisfactory results. Where infestations are spotty or are confined to fencerows, hand equipment will provide satisfactory control if treatment is made while the grasshoppers are still in clusters or colonies. Thorough dusting or spraying of the area occupied by the colonies is all that is required. Where the infestation is scattered over large areas any equipment which can be calibrated to apply the required amount of insecticide per acre can be used satisfactorily.

SUMMARY.—Numerous reports of damage to cultivated crops by the American grasshopper, *Schistocerca americana* (Drury), were received from southeastern United States in 1950. In 1951 experiments were undertaken to investigate insecticides to control this species in that section.

The investigations were conducted on small plots with hand equipment and large plots and in the field with power equipment. All tests were made on first-generation nymphs from May 3 to June 13.

Materials used as dusts in the small-plot tests were commercial preparations containing 2.5 per cent of aldrin at 4.4, 9.6, and 10.4 ounces, 10 per cent of toxaphene at 2.55 and 3.45 pounds, 5 per cent of chlordane at 1.30 and 1.42 pounds, 2 per cent of parathion at 6.24 and 9.6 ounces, 1 per cent of parathion at 3.1 ounces, and 3 per cent of lindane at 12.5 ounces of active ingredient per acre. Emulsion concentrates applied as sprays to the small plots were dieldrin at 1.5 ounces, aldrin at 5 ounces, and heptachlor at 4 ounces of active ingredient per acre. With the exception of the lindane and the 1 per cent parathion dusts, all treatments gave satisfactory control of the grasshoppers, with average mortalities of 91 per cent or higher 3 days after treatment and 88 per cent or higher in 5 days.

Emulsion concentrates only were used in the large-plot tests and were applied at the following rates per acre: Dieldrin at 1.5 ounces, heptachlor at 2 ounces, aldrin at 2 and 4 ounces, chlordane at 1 pound, toxaphene at 1.5 pounds, and lindane at 0.5 pound of active ingredient. With the exception of lindane, all materials gave average grasshopper mortalities of 94 per cent or higher in 3 days and 93 per cent or higher in 5 days.

LITERATURE CITED

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Host-Plant Resistance as a Factor Influencing Population Density of Citrus Red Mites on Orchard Trees[1]

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Until recently, the citrus red mite, *Paratetranychus citri* (McG.), has been considered native to North America (Ebeling 1951). In 1949, however, red mites were collected from citrus trees on the campus of Lingnan University at Canton, China, by J. L. Gressitt of the Division of Biological Control of the University of California. These mites were identified by E. W. Baker of the United States National Museum as *Paratetranychus citri* (McG.). After the discovery of *P. citri* in Canton, it was found in Japan by Gressitt and in Formosa by T. C. Maa. Since citrus is native to the Orient and is the preferred host of this mite, it seems quite logical to conclude that the citrus red mite is native to the Orient.

The citrus red mite is now one of the major pests of citrus in southern California. The history of this mite and of the studies of biological and physical factors affecting it has been reported by DeBach *et al.* (1950). In this report of several years of intensive field study, it was stated that studies in citrus groves which had received no insecticidal applications for from 3 to 10 or more years indicated that predators were the factors generally responsible for the reduction of citrus red

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mite populations, or for the maintenance of such populations at low levels. It was also pointed out, however, that reductions in certain citrus red mite populations in the fall of the year were caused by unknown factors. In the hope of gaining some insight into the nature of these "unknown factors," the present studies on host-plant resistance as a factor influencing citrus red mite populations were undertaken.

HOST-PLANT RESISTANCE.—The expression "host-plant resistance," as used in this paper, refers to the capacity of the plant to repel or oppose attack by the citrus red mite. Resistance in some citrus plants may be so marked that they are practically immune to mite attack; in others it may be so slight that they are highly susceptible. Thus, under favorable meteorological conditions, host-plant resistance delimits the ultimate mite population attainable on a given plant at a given time.

Host-plant "resistance" must not be confused with host-plant "tolerance": "resistance" is the plant's capacity to oppose mite population increases; "tolerance" is the plant's ability to withstand a mite attack of given intensity. For example, a plant may be markedly resistant to mite attack, but its tolerance may be so low that even a light infestation of mites may cause serious injury. Conversely, a plant may offer little resistance to mite attack, but its tolerance may be such that it can withstand a relatively high population of mites without being seriously injured. Examples of both types have been observed in the field.

The citrus plant may offer resistance to mites through mechanical means such as the thickness or physical condition of the cuticle or epidermis, or it may offer resistance through biochemical constituents of the plant, namely, through the presence of toxic or repellent substances or the scarcity of certain required nutrient materials.

To date there have been no field studies to evaluate the resistance of citrus trees to citrus red mite attack in the absence of natural enemies. However, as a result of experimental studies on the population increase of citrus red mite associated with the use of sprays containing inert granular residues, Holloway *et al.* (1942) concluded that sprays containing zinc caused a significant increase in citrus red mite populations. Although predators were not eliminated by the zinc sprays, the increase in mite populations was not attributed to biological control factors; neither was it attributed to a direct chemical or physical stimulus on the longevity or egg production of the citrus red mite.

Henderson & Holloway (1942) concluded, from laboratory experiments, that the citrus red mite produced significantly greater numbers of eggs on young and medium-aged leaves than on older leaves.

Whitcomb *et al.* (1943), working with greenhouse plants, reported that the lower the pH of the sap of rose and carnation plants, the less the time required for the common red spider mite to develop from hatching to adult. Garman & Kennedy (1949), working with bean and peach plants grown in sand cultures in the greenhouse, showed that either plant would produce higher populations of two-spotted spider mites when heavily fertilized. Huffaker & Spitzer (1950), working with two-spotted mites on pears, state that DDT treatments produced an increase of mite populations above that occurring on check trees under conditions which, though not understood, were not explainable on the basis of the natural enemies.

EXPERIMENTAL PROCEDURE.—To determine the degree of resistance of the host plant to mite attack, it was necessary to remove the natural enemies of the mites without changing the environment in any other way. This requirement obviously precludes the use of any sort of cover or insecticide to protect the mites from their natural enemies. In the final analysis it was decided to use the tedious, time-consuming, but highly effective method of removing the natural enemies by hand-picking. This method demanded that one person give his full attention to a single tree from morning until night, 7 days a week, for an extended period of time. In this manner the natural enemies of mites were removed from five trees in five different groves. The time duration for which a single tree was under observation ranged from 2 weeks to 87 days, a total of 231 days being spent in the five experiments. Data obtained from four of these groves are discussed in this paper. In the course of these experiments neither

disease organisms nor meteorological factors, as such, were responsible for reductions in mite populations. The general reductions which occurred on these trees were therefore attributed to host-plant resistance.

The experiments were set up in four citrus groves. The Walker grove, located in Orange County, near El Toro, California, is planted to Valencia orange trees that were about 12 years old when the experiment was started. The experiment was set up on May 15, 1950, and terminated 47 days later, on July 1. The Basinger grove is a Valencia orange grove near Riverside. The experimental tree was a 5-year-old replant. The experiment was set up on March 12 and terminated June 6, 1951. The Compere grove is a 20-year-old navel orange grove in Riverside. The experiment in this grove was started on October 3 and terminated November 6, 1951. The Utt grove, in Oxnard, Ventura County, is planted to Allen Eureka lemon trees, which were 17 years old when the experiment was started, in 1949.

For each experiment two neighboring trees were selected for similarity in size, age, physical condition, and mite population density. One of the trees was arbitrarily chosen to be used as the experimental tree; the other was used to study the effect of natural enemies on the mite populations. Although a study of the effect of natural enemies is not an integral part of a study of host-plant resistance, some very interesting information was obtained in this manner and will be discussed later.

Once the experiment was started, the experimental tree was under constant observation all day long, every day, for the duration of the experiment. Eight twig terminals consisting of two terminals from each quadrant of the tree were selected for count terminals, tagged, and numbered. One of the terminals from each quadrant bore leaves about 1 year old; the other bore recently matured flush-growth leaves. All count terminals were between knee and shoulder height. Ants were eliminated by pruning the skirts of any affected tree and dusting the soil around the base of the tree with chlordane.

The total number of mature female mites on the first four fully formed leaves of each count terminal was recorded

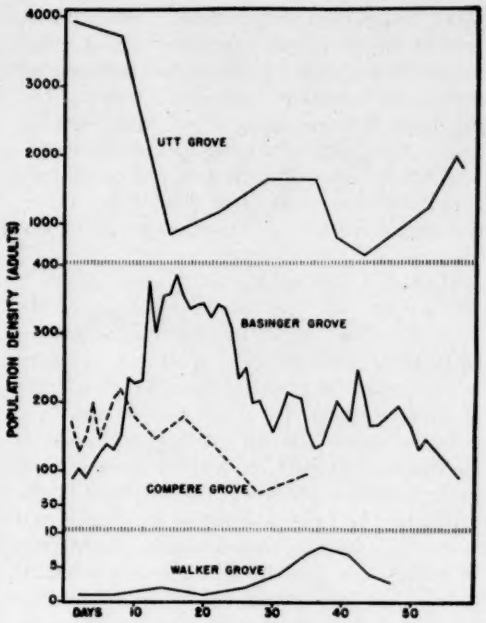

FIG. 1.—Relative degree of host-plant resistance to attack by citrus red mite in four citrus groves in southern California.

daily. A separate record was kept of counts for each terminal. In addition, two count terminals on a given quadrant of the tree were selected for more careful observation than the others. The first four leaves of each of these two terminals were numbered from 1 to 4. With the aid of a 10× hand lens, the numbers of eggs and of young and mature mites on each of these leaves were counted daily, in the morning and in the late afternoon, and separate records were kept for each leaf. Thus the morning records could be compared with the records of the previous evening to ascertain whether or not any eggs or mites had disappeared during the night. (It was soon learned that there was little mite or predator activity during the night.)

A constant search was maintained for predators on the experimental tree, and all predators found within reach of the observer were collected in an aspirator. The eight count terminals of each tree were given special attention and were carefully examined at 10- to 15-minute intervals throughout the day. The two terminals selected for more careful observation than the others were kept under constant observation except for the peri-

odic inspection trip made around the tree at 10- to 15-minute intervals. A daily record was kept of the total number of predators removed, separate records being kept for the number of eggs, larvae, pupae, and adults of each species of predator. At the close of each day, the predators that had been collected were released in the grove five or six trees away from the experimental tree.

RANGE OF HOST-PLANT RESISTANCE.—The range of host-plant resistance observed in four experimental citrus groves from 1949 through 1951 is shown in figure 1. It should be pointed out that the units of measurement for mite populations are not the same for all curves in figure 1. In the curve for the Walker grove, each unit denotes a mite population of one mite; in the curves for the Basinger and Compere groves, each unit represents 10 mites; and for the Utt grove, each unit represents 100 mites. If the curve for the mite population of the Utt grove were shown on the same scale as that for the Walker grove, a chart about 40 times the height of the present one would be required. The curve for the Utt grove depicts the mite population of one tree, from October 6 to December 2, 1949. Samples were taken from this grove at approximately weekly intervals, and predators were not removed. The data from this grove are used in figure 1 because they show that citrus trees are capable of supporting tremendous population of citrus red mites when the host-plant resistance is low. All the groves represented in figure 1 are good producers and receive excellent care.

Each point on the curves in figure 1 represents the mite population on a 32-leaf sample from a single tree. For the entire period shown on the graph, natural enemies of mites were removed from the trees of the Walker, Compere, and Basinger groves by hand-picking; they were not removed from the tree in the Utt grove. As shown in figure 1, host-plant resistance in the Walker grove was so marked that the maximum mite population reached was 8 mites per 32-leaf sample; the degree of host-plant resistance was so low in the Utt grove, however, that even though natural enemies were present on the tree, the mites attained a population of 3941 per 32-leaf sample. Mite populations in the Basinger grove peaked at 388 mites per 32-leaf sample, and in the Compere grove they peaked at 220. The discrepancies depicted by these four curves certainly represent a marked degree of variation in host-plant resistance.

PROGRESS OF AN ARTIFICIAL INFESTATION OF CITRUS RED MITES ON A HIGHLY RESISTANT HOST PLANT.—At the time the experiment in the Walker grove was started, the mite infestation was very low (Fig. 1). Because the population of natural enemies was also low, with the number of predators found per day on the experimental tree ranging from 0 to 7, it was a simple matter to keep the count terminals free of natural enemies. It was therefore decided to study the progress of an artificial infestation of mites on the experimental tree, and on May 15 eight terminals free of mites and eggs were infested with 10 mature female mites on each of the first four fully formed leaves—a total of 40 mites on each terminal. Daily records of eggs and of young and mature mites resulting from this artificial infestation on one representative terminal are shown in figure 2. By May 25 the mites had deposited a total of 156

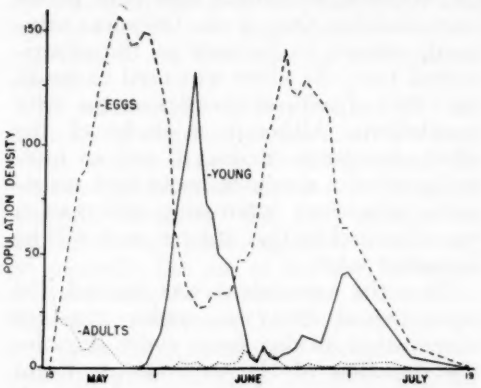

FIG. 2.—Populations of adults, eggs, and young mites resulting from an artificial infestation of 40 adult citrus red mites on one representative terminal of the experimental tree in the Walker Valencia orange grove, near El Toro, California.

eggs. The number of young mites hatching from these eggs peaked at 131 on June 6. Few of the young mites reached maturity; some died on the count leaves and others crawled away, supposedly seeking more satisfactory feeding areas. Many of the young mites that crawled away were found dead on the older leaves

of the terminal, below the count leaves, presumably starved to death. However, the adults that developed from this first generation of young mites produced an egg population which peaked at 142 on June 20, with a resulting peak of 43 young on June 30. At this time the adult population consisted of 2 mites, a decrease of 38 mites from the original 40. Since meteorological conditions were favorable for mite increases, and since natural enemies, including diseases, were not operative during this experiment, it was concluded that host-plant resistance was primarily responsible for the resultant decrease in the adult mite population.

SOME EFFECTS OF INERT AND CHEMICAL RESIDUES ON HOST-PLANT RESISTANCE TO CITRUS RED MITES.—Shortly after the experiments in the Walker grove were started it was perceived that an excellent opportunity had presented itself to study the effects of various residues on host-plant resistance to mite attack, and it was decided to test the effect of residues of field dust and of zinc-deficiency and DDT spray materials in this respect.

On June 10 two mite-free terminals were treated with DDT, two with zinc, two with field dust, and two were designated as checks. DDT was applied to the twig terminals in a mixture the equivalent of 4 pounds of 25 per cent wettable DDT to 100 gallons of water. The zinc treatment was a mixture the equivalent of 6 pounds of zinc sulfate and 3 pounds of hydrated lime to 100 gallons of water. In order to apply these mixtures to a given terminal without contaminating neighboring leaves, a 2-quart, wide-mouthed Mason jar was three-quarters filled with the mixture to be applied, and the terminal was momentarily immersed in the mixture, care being taken to keep the mixture thoroughly agitated all the while. The jar was then carefully withdrawn until the terminal was just free of the liquid, and it was held in this position to allow the excess material to drip from the terminal back into the jar. In order to obtain a heavy deposit of field dust on two of the terminals, a handful of dust from the field was placed in a dry 2-quart jar; the terminal to be dusted was placed in the jar, and one hand with thumb and forefinger around the stem covered the mouth of the jar; the jar was first shaken briskly, then held still until the dust had settled, and then carefully removed.

On June 11, one day after the treatments, and again on June 19, ten mature female mites were placed on the first fully formed leaf of each of the experimental terminals, including the checks. Daily records were kept of the numbers of eggs and of young and adult mites occurring on each of the first four fully formed leaves of each terminal. The daily totals of mite eggs obtained from June 12 to June 30 from counts on the DDT-treated, zinc-treated, and check terminals are shown in figure 3. Daily observations and the removal of predators were discontinued on June 30, but weekly records were taken from July 1, 1950, through January 3, 1951. Weekly records from July 1 through November 2, 1950, are shown in figure 3.

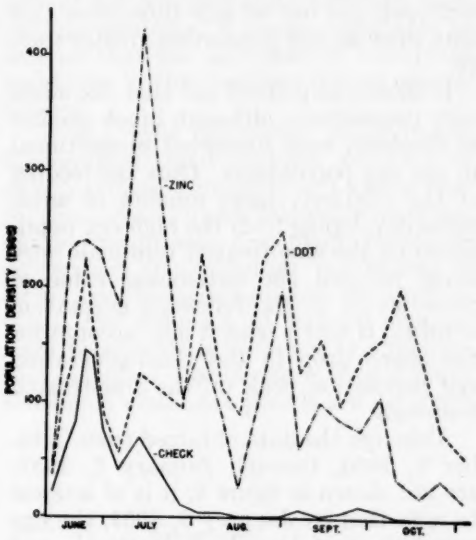

FIG. 3.—Total numbers of eggs produced by artificial infestations of 20 adult female citrus red mites per terminal on two check terminals, on two terminals treated with a zinc-deficiency spray, and on two treated with DDT, on the experimental tree in the Walker Valencia orange grove.

As shown in figure 3, from the first day until the end of the experiment there were fewer mite eggs on the check terminals than on either the DDT-treated or the zinc-treated terminals. On June 23 the first-generation egg population peaked at 145 on the check terminals, at 224 on the DDT-treated terminals, and at 241 on the zinc-treated terminals. On June

24 all egg populations began to decrease as a result of the hatching of the young mites. Some of these young mites had matured and were beginning to produce eggs on July 5, at which time all the egg populations began to increase sharply. By July 12 this second-generation egg population had reached a total of 68 on the check terminals, 125 on the DDT-treated terminals and 422 on the zinc-treated terminals. The third-generation egg population peaked on August 2 with a total of 4 for the check terminals, 152 for the zinc, and 230 for the DDT. The DDT terminals which had been a weak second to the zinc in the second-generation egg peak had gained a strong lead by the third-generation peak, and this they kept for the duration of the experiment. Although the zinc and DDT terminals maintained a fair population of mites through November 2, the check terminals did not at any time after this date show an egg population greater than 10.

It should be pointed out that the adult mite populations, although much smaller in numbers, were somewhat proportional to the egg populations. Thus the feeding of the relatively large number of adult mites developing from the high egg population on the zinc-treated terminals very likely reduced the nutritional value of these leaves to the following generation of mites. If this is true, it may account for the sharp drop in the third-generation egg population peak on the zinc-treated terminals.

Although the data obtained from October 2, 1950, through January 3, 1951, are not shown in figure 3, it is of interest to note that by January 3, 1951, the egg populations of the check terminals and of those treated with field dust and zinc were zero; the egg population of the DDT-treated terminals, however, was 198 at this time.

The egg populations that developed on the terminals treated with field dust (not shown in figure 3) were somewhat similar to those on the zinc-treated terminals, which reached a peak of 495 eggs on July 27. After this date they were somewhat lower than the populations on the zinc terminals, and by October 4 they were approximately the same as the egg populations on the check terminals.

The data from this experiment indicate that the residues of field dust, zinc sulfate-lime deficiency sprays, and DDT sprays, lowered the host resistance of citrus plants to citrus red mite attack. These data also indicate that, after a period of time, the DDT spray material produced a mutation in the citrus leaves which rendered these leaves less resistant to citrus red mite attack, and that this state of lowered resistance persisted in the leaves for a period of more than 7 months.

At the same time that the terminals were treated to test the effect of field dust, DDT, and zinc deposits on the host-plant resistance of citrus trees to citrus red mite attack, four additional terminals were treated (two with zinc and two with DDT) to test for the possible translocation of any weakening effect of these materials on the host-plant resistance. The same application procedure was used in these tests as in those described above, except that the terminal leaves down to and including the fourth fully formed leaf were not treated. Leaves 5 through 8 were swabbed with the separate mixtures to be tested. The same check terminals used in the preceding experiments were used for these experiments. Here again the artificial infestation of mature mites was placed on the first fully formed leaf, which in this case, however, was a clean or untreated leaf.

The daily totals of mite eggs obtained from the first four fully formed (un-

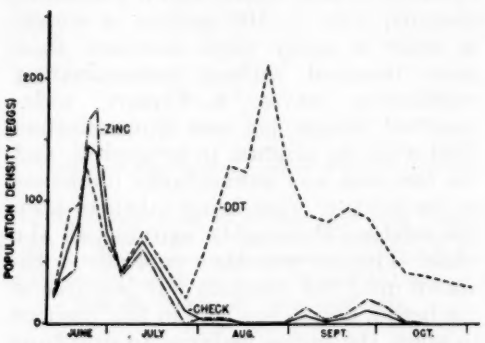

FIG. 4.—Total numbers of eggs produced by artificial infestations of 20 adult female citrus red mites per terminal on the four untreated leaves growing above older, treated leaves on each terminal. Older leaves on two terminals were treated with a zinc-deficiency spray material, and on two other terminals were treated with wettable DDT; two untreated terminals were used as checks. All terminals were on the experimental tree in the Walker Valencia orange grove.

treated) leaves of the respective terminals from June 12 through June 30, and the weekly totals obtained from July 1 through November 2, 1950, are shown in figure 4. For the first 45 days, the check and test terminals agreed closely in total numbers of eggs produced. These results might well be expected, since none of these leaves were treated. After 46 days, however, the numbers of eggs produced on the untreated leaves on the same terminal with the DDT-treated leaves were far in excess of those produced on the check or zinc-treated terminals. Though not shown in figure 4, weekly samples of egg populations on these terminals were taken through January 3, 1951. On this date the total egg population on the untreated leaves above the DDT-treated leaves was 126, whereas the egg populations on both the check and the zinc-treated terminals were zero. The high egg population on the leaves above the DDT-treated leaves could not have been due to inhibited predator activity, since these leaves were untreated; furthermore, the DDT deposit on the lower leaves at this time was no longer effective against the natural enemies. Therefore, these experiments indicate that there is some translocatable change produced by DDT in citrus leaves which serves to lower the resistance of the plant to attack by citrus red mite.

GENETICS AS A FACTOR IN HOST-PLANT RESISTANCE.—It has long been known that some species of citrus are less resistant to citrus red mite attack than others. Ebeling (1951) states that lemon appears to be the preferred host, but that orange and grapefruit may also be severely attacked.

There is good evidence that intraspecific variation in inherited host-plant resistance may be rather marked. One outstanding example was observed in a nursery planting on the Hardison Ranch Company property in Santa Paula. In one of the nursery rows a number of nucellar seedlings of lemon treees are growing side by side in pairs supposed to be genetically identical. Each pair originated from a different parent lemon tree. For a period of several months the citrus red mite population on one pair was approximately ten times higher than that found on any of the other pairs. Since all these trees were in the same nursery row and all were subject to the same meteorological conditions and natural enemy activity, and, especially, since both members of the one pair had excessively high mite populations, it seems reasonable to assume that the difference in host-plant resistance in this case was due to genetic factors.

INTERACTION BETWEEN HOST-PLANT RESISTANCE AND PREDATOR ACTIVITY IN THE NATURAL CONTROL OF CITRUS RED MITES.—Since, under favorable meteorological conditions, host-plant resistance determines the potential population of citrus red mites attainable on a given plant, the influence of natural enemies must be effected at or below this population potential. For instance, if host-plant resistance would not permit a mite popu-

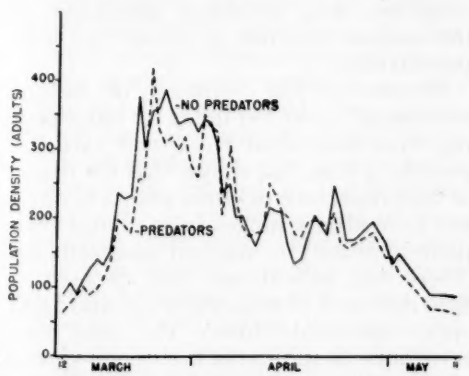

FIG. 5.—Effect of host-plant resistance on population density of adult citrus red mites on two neighboring trees in the Basinger Valencia orange grove, Riverside, California. Mite predators were present on one tree and absent from the other.

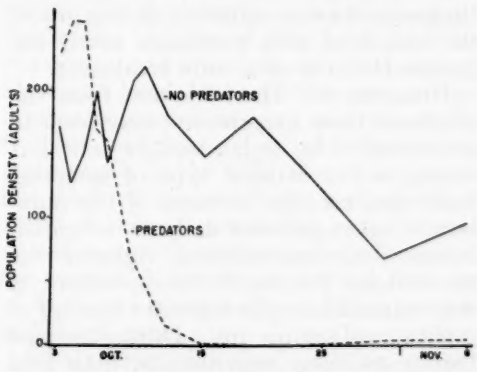

FIG. 6.—Population density of adult citrus red mites on two neighboring trees in the Compere navel orange grove, Riverside, California. Mite predators were present on one tree and absent from the other. Mite reduction due entirely to action of natural enemies.

lation greater than four mites per leaf, then the mite population would not increase beyond this point even in the total absence of natural enemies; but any population of four mites or less per leaf on such a plant could be reduced by an effectively working population of natural enemies.

An example of a mite population which was restricted by host-plant resistance and was not significantly reduced by the natural enemy complex operative within the grove is shown in figure 5 (Basinger Valencia orange grove). Figure 6 (Compere navel orange grove) shows a mite population which was strikingly reduced below the extreme tolerated by host-plant resistance. This marked reduction was due entirely to the action of natural enemies. In each of these figures the two curves represent the mite population densities on two neighboring trees of the same age. Natural enemies of mites were kept from one of the trees by hand-picking throughout the periods shown in the figures; the enemies had free access to the other tree at all times.

As shown in figure 5, there was no significant difference between the mite populations on the two trees in the Basinger grove at any time. The predator activity in this grove at this time was not sufficient to reduce the mite population below the extreme tolerated by host-plant resistance. In figure 6, however, it may be seen that, where predator activity was permitted, it quickly reduced the mite population to approximately zero, whereas the mite population remained relatively high on the tree from which the predators were removed. In this grove, the action of mite predators saved the grower the cost of a mite treatment.

DISCUSSION.—The inferences from the results of these experiments may seem to be supported by rather meager data, but owing to the detailed type of sampling technique, *e.g.*, the counting of the numbers of mite eggs twice daily on individual leaves, and the constant vigilance demanded by the search for predators, it was impossible to use a greater number of replicates of sample units. During the past two years many experiments, both field and laboratory, have supported the general indications given in this paper.

Some general hypotheses may be drawn from these experimental data. For instance, when the mite population in the Basinger Grove (Figs. 1 and 5) began to decline, the decrease was more or less proportional on all ages of leaves. Hence we may hypothesize that this reduction was not due to mechanical resistance such as thickness of cuticle or epidermis, but was due to some change in the amount or condition of the nutrient material which the mites obtained from the leaves. The delayed effect of DDT in causing a lowering of the resistance of the citrus plant to mite attack could operate in a like manner.

In cases in which the inert residues lowered host-plant resistance, it may be hypothesized that these materials modified the leaf surface in some manner, *e.g.*, by inducing an increase drate of transpiration, so as to create a more suitable ovipositional substrate. In any event, it is indicated that various types of dust deposits lower the host-plant resistance to citrus red mite attack, and that physiological changes within the plant have a marked effect on such host-plant resistance.

The proper manipulation of these various factors may be of utmost importance in achieving satisfactory biological control of the citrus red mite, not only because of the effect on host-plant resistance, but also because of the effect on another important factor which will be discussed in a later paper, namely, mite-predator ratio. For these reasons, present studies on the biological control of the citrus red mite in southern California include experiments on the effects of such factors as fertilization, cover crops, soil condition, and overhead sprinklers on the natural balance of citrus red mite populations.

SUMMARY.—The removal of natural enemies of citrus red mites by hand-picking from individual trees over extended periods of time, has shown that the degree of host resistance of citrus plants to citrus red mite attack ranges from almost complete immunity to marked susceptibility. There are indications that deposits of field dust and of zinc-deficiency and DDT spray materials lower the host-plant resistance to mite attack through certain physical properties of these materials. There are also indications that the DDT spray material produces some change within the citrus leaves which causes a lowering of the host-plant resistance

some time after application, and that the changes developed within the citrus leaves are translocated from older to younger leaves.

Intraspecific variation in host-plant resistance was observed. Young citrus leaves tend to have less resistance to mite attack than older leaves. The action of natural enemies may reduce a citrus red mite population to approximately zero, even though the host plant offers relatively little resistance to attack by citrus red mite.

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Seasonal Populations of Cabbage Caterpillars in the Charleston, S. C., Area

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During a study of factors influencing infestations of the different species of lepidopterous larvae that attack cabbage, a systematic count of insect populations was made in representative fields in the Charleston, S. C., area over a 4-year period (fall of 1935 through spring of 1939). Most of these fields were operated by independent growers who applied various insecticides—arsenicals, cryolite, and rotenone-containing dusts—whenever in their opinion such applications were warranted. In some fields insecticides were not used. Records were simply made of existing conditions, and growers were not specifically advised in the selection of insecticides or in the method or time of applying them. Bare (1940) discussed the diverse control practices employed and, by determining the crop losses due to attack of caterpillars, demonstrated that these practices were inadequate. This inadequacy seemed to be due in part to ineffective timing of insecticide applications, which requires, among other things, a knowledge of the seasonal occurrence of injurious infestations. The present paper shows the seasonal trend of caterpillar populations, by species, in the cabbage fields under observation and how if affects the problem of formulating more effective control measures.

In the vicinity of Charleston two crops of cabbage are produced each year, the fall and the spring crops, the growing periods of which often overlap in midwinter. The fall crop is seeded in the open fields from the last of July until early in September and is harvested in November, December, and January. The spring crop is usually seeded in open plant beds in October and November, the plants are transferred to the field from about the last week of November through the first week of February, and the crop is harvested more or less continuously from the last week of March through the last week of May and occasionally until about the middle of June.

The survey described in this paper covered the 8 crop seasons between the summers of 1935 and 1939.

METHODS.—Of the total of 8 cabbage

[1] In cooperation with the South Carolina Agricultural Experiment Station. Credit is due C. F. Stahl, L. B. Reed, and Chas. E. Smith, of the Bureau of Entomology and Plant Quarantine, for important contributions.

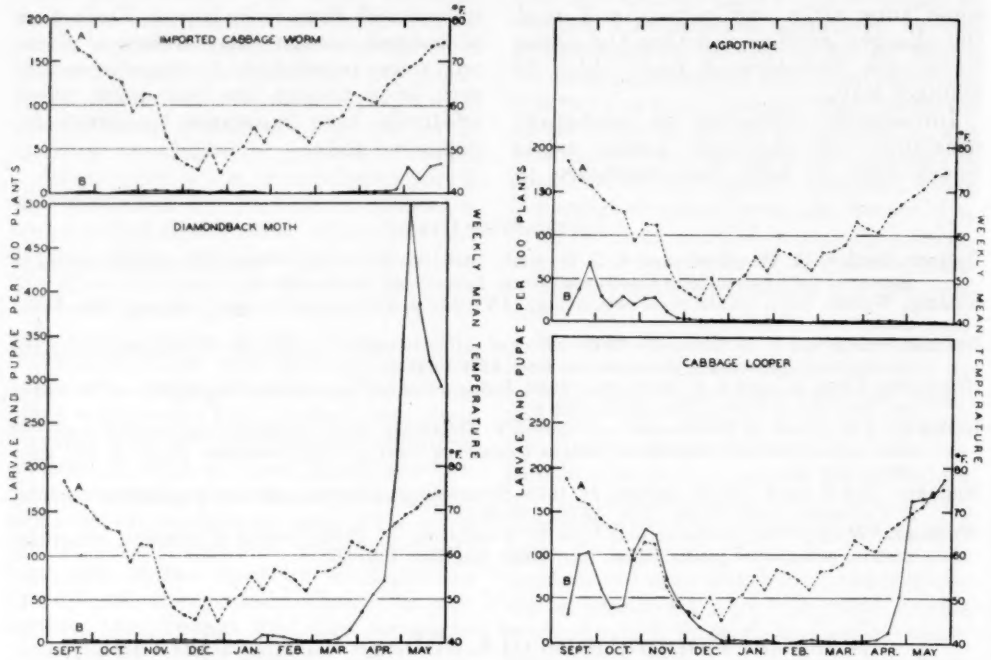

FIG. 1.—Average weekly mean temperatures in relation to the population of cabbage caterpillars that survived commercial control practices, in the vicinity of Charleston, S. C., 1935–39. A. Temperature; B, insect populations.

crops involved, 4 were grown in the spring and 4 in the fall. One hundred plants, in 4 adjoining rows of 25 consecutive plants each, composed a block. Two such blocks were staked off in each field, being located at random in diagonally opposite quarters. The fields differed in size, in the variety and age of the cabbage plants, and in cultural and insecticidal treatment. These blocks included a total of 5400 plants in 27 fields on the farms of 17 growers during the 8 crop seasons. Five fields were under observation during each of the first 4 seasons, from the fall of 1935 through the spring of 1937, 2 fields in the fall of 1937, 3 in the spring of 1938, and one each in the fall of 1938 and the spring of 1939.

The numbers of larvae and pupae of each species present on each plant selected for study were recorded weekly. The counts were begun on the fall crop after the plants had been thinned to the desired stand and on the spring crop after the transplants had become established. The counts were continued until the plants were harvested. The larvae were classed as small, medium, and large. As soon as counting and recording were completed, the fully grown larvae and the pupae were removed from the plants.

Supplementary observations were made on 100 cabbage or collard plants each week during the summers of 1937 and 1938, during January 1938, and during January, February, June, and July 1939, to obtain data for those periods of the year when there were no commercial plantings of cabbage under observation.

PRESENTATION OF DATA.—The average number of larvae and pupae per 100 plants found on commercial-crop plants during the various seasons, together with the number of plants involved and the average prevailing mean temperatures, are shown by weeks in table 1. Data for several weeks have been omitted from this table because of the accumulation of days exceeding 4 weeks in each month. Such a method of combining the observations of the various seasons does not give equal weight to each week and season, because of variations in the number of plants examined, this variation being due to differences in the number of fields involved and also to gradual harvesting of the plants. The grouping, as presented, serves the purpose of this paper, however, by giving a general picture of the caterpillar populations under prevailing conditions during the seasons involved.

Table 1.—Average weekly populations of cabbage caterpillars that escaped commercial control practices on cabbage in vicinity of Charleston, S. C., 1935–39.

Month and Week	Number of Years	Number of Plant Examinations	Mean Temperature, F.°	Average Number[1] of Larvae and Pupae Found per 100 Plants			
				Cabbage Looper	Diamondback Moth	Imported Cabbageworm	Agrotinae
September:							
Second	2	400	77.0	30.2	0.5	0	7.0
Third	3	1,000	72.5	100.3	3.0	.1	36.0
Fourth	3	1,595	71.4	101.0	2.8	.6	69.1
October:							
First	3	1,395	68.1	60.1	1.6	0	30.1
Second	4	1,793	66.2	38.8	1.3	0	18.4
Third	4	1,784	65.2	42.8	1.6	.1	30.7
Fourth	4	1,751	58.5	104.8	2.4	.7	21.3
November:							
First	4	1,700	62.7	128.5	2.2	.8	27.7
Second	4	1,611	62.2	123.1	2.6	.9	28.4
Third	4	1,446	53.2	73.2	2.7	.8	12.2
Fourth	4	1,201	48.0	46.1	3.8	.8	5.3
December:							
First	4	999	46.5	30.8	3.9	.9	3.0
Second	4	830	45.1	17.0	2.5	.5	1.3
Third	3	687	50.4	11.5	1.0	0	.8
Fourth	3	544	44.6	2.8	.8	.6	.6
January:							
First	3	416	49.2	2.6	1.0	0	.7
Second	3	414	50.6	1.2	.9	.5	.5
Third	3	286	55.2	.3	0	.7	.7
Fourth	4	383	51.6	2.9	9.9	0	1.3
February:							
First	2	300	56.6	0	7.3	0	.7
Second	2	299	55.8	0	6.0	0	.3
Third	3	796	54.2	2.2	3.0	0	0
Fourth	4	996	51.7	3.0	1.4	0	0
March:							
First	4	996	56.2	2.1	1.6	0	.3
Second	4	1,594	56.3	1.2	2.2	0	.3
Third	4	2,185	57.8	1.6	5.1	.1	.1
Fourth	4	2,177	63.1	2.5	14.9	.4	.4
April:							
First	4	2,332	61.7	2.6	34.0	1.6	3.4
Second	4	2,418	60.6	4.4	54.4	1.6	3.1
Third	4	2,480	65.0	12.0	70.1	2.5	3.1
Fourth	4	2,311	67.0	52.1	195.3	4.1	2.0
May:							
First	4	1,969	69.0	163.0	497.0	31.8	.6
Second	4	1,738	70.5	165.1	385.9	15.3	.3
Third	4	1,324	73.6	167.2	321.1	31.6	.5
Fourth	4	1,012	74.4	186.4	293.4	34.6	.2
Average, all weeks		1,290	59.8	48.1	55.3	3.8	8.9

[1] Weighted in accordance with number of plants examined.

The seasonal trend of the populations of the more abundant species on commercial-crop plantings and the prevailing average weekly mean temperatures are shown in figure 1.

DISCUSSION.—Considering the commercial-crop seasons as a whole and the control practices used, the cabbage looper (*Trichoplusia ni* (Hbn.)) and the diamondback moth (*Plutella maculipennis* (Curt.)) were the most abundant of the Lepidoptera found on cabbage in the Charleston area, the diamondback moth being slightly more numerous than the looper. The other species found were the imported cabbageworm (*Pieris rapae* (L.)), the Agrotinae,[1] and the cabbage webworm (*Hellula undalis* (F.)). Data pertaining to the cabbage webworm were not included in table 1 and figure 1, because of the small numbers found on the

[1] The corn earworm, *Heliothis armigera* (Hbn.), the fall armyworm, *Laphygma frugiperda* (A. & S.), and several species of cutworms.

commercial plantings after the plants were thinned or transplanted. Supplementary observations indicated that the cabbage webworm is an important pest of seedling plants of the fall crop and are most abundant during the latter half of July, all of August, and the first week of September. An occasional webworm was found until the first week of November.

Inasmuch as the plants involved in this survey were subjected to the insect-control measures practiced by various growers, most of whom used insecticides at some time during the growth of the crop, the data given in table 1 are regarded only as an indication of the seasonal trends and peaks of caterpillar infestations on cabbage in the Charleston area under the existing conditions. They also show the approximate time when additional control measures should be undertaken, and against what species they should be directed. The data should not be considered as a true index of conditions that would have prevailed had no control measures been used. It was evident from field observations that the development of the infestations was retarded by the insecticide applications, and that some species were affected more than others, depending on the insecticide applied. For example, the imported cabbageworm seemed to be more susceptible than the others to all the insecticides, and the Agrotinae were resistant to pyrethrum and rotenone, as reported by Reid *et al.* (1941).

After the thinning of the fall-crop plants, which is usually done in September, the cabbage looper and the Agrotinae comprised practically the entire caterpillar population. An occasional cabbage webworm was found, and that species had evidently been much more abundant during the seedling stage. The average peak of the cabbage looper infestation of the fall crops occurred during the first and second weeks of November and that of the Agrotinae during the third and fourth weeks of September (Table 1). When all species were considered together, it was evident that the caterpillar population on the fall crop reached high points during the latter half of September and again during the first half of November.

On spring-crop plants, after they had been transplanted to the field, the diamondback moth was the most numerous species, the cabbage looper next in abundance, and the imported cabbage worm third, all these species appearing in appreciable numbers. The average peak of the diamondback moth population came during the first week of May and that of the cabbage looper and the imported cabbageworm covered the greater part of that month. The two last-named species were slightly more abundant in June than in May, but these populations occurred on plantings being grown later in the season than was the bulk of the commercial crop. The peak of the combined population of the commercial spring crop came during the first week of May.

All the five species mentioned heretofore were found throughout the summer on either cabbage or collards, plantings of which were very scarce at that time of year. The looper and the diamondback moth were found on commercial cabbage plantings during the greater part of mid-winter, but in greatly reduced numbers, as compared with the spring and fall populations. Occasional Agrotinae and imported cabbageworms also were taken during mid-winter.

The average combined population of all species showed a marked decrease when average weekly mean temperatures fell to or below about 50° F. after the middle of November. The population remained at a comparatively low level until weekly mean temperatures were consistently above about 60°. The upward trend of infestations usually began during the latter half of March. Control measures were found to be worth while when the caterpillar population reached an average of about one caterpillar per plant (100 caterpillars per 100 plants), which usually occurred about the third week of April during the course of the studies.

Apparently the conditions of mean temperature and caterpillar population indicated in table 1 and figure 1, with the exceptions noted regarding the effects of the insecticides used, represent about what might be expected during an average season in the Charleston area. Other than the unusual abundance of Agrotinae during the fall of 1935, there were no particularly abnormal conditions of temperature or of caterpillar population while the survey was in progress. Average mean temperatures prevailing in the cabbage-growing area during the critical months

from November to April over the entire period of the survey were 56.5°, 46.6°, 51.6°, 54.6°, 58.4°, and 63.6° F., as compared with the 68-year means of 58.2°, 51.5°, 50.6°, 52.1°, 57.8°, and 64.8° for the same months, as recorded by the Weather Bureau (1939) in Charleston. The difference of 0.6° per month between the locations was to be expected.

That different caterpillar populations from those described in this paper can be expected in the Charleston area under more abnormal temperatures was demonstrated during the unusually mild winter of 1931–32. Weather Bureau records (1931 and 1932) show that there was no killing frost that winter until March 10, and that the monthly mean temperatures fom November 1931 to April 1932 were 63.0°, 61.3°, 60°, 60°, 55.4°, and 66.2° F. In other words, such temperatures did not go below 50° and were below 60° only in March, when the caterpillar populations had reached very high levels.

Severe injury by the cabbage webworm to young cabbage plants in plant beds was observed in December 1931 in the Charleston area. The diamondback moth also was present in plant beds that month, and continued to breed throughout the winter and spring, reaching extremely high population levels (as many as 50 larvae on one collard leaf) and caused severe damage to 75 per cent of the spring-crop cabbage plantings. Ninety per cent of the plants in individual fields were heavily infested.

Cabbage caterpillar populations were observed during the survey to have been influenced by several factors besides temperature, chiefly the generation cycles of the various species, the stage of development and condition of the plants, the amount and distribution of rainfall, the nearness of a planting to sources of infestation, and the magnitude of the initial infestation.

SUMMARY.—A study was made of seasonal populations of the caterpillars attacking cabbage in representative commercial plantings in the Charleston, S. C., area, to most of which growers applied the usual control practices. The survey extended from the fall of 1935 through the spring of 1939—eight crop seasons—and and included a total of 5,400 plants. Each plant was examined each week during its period of growth from the time of thinning or transplanting to harvest or premature death. This article describes findings regarding the seasonal trends of the caterpillars under the existing conditions and indicates the time when additional control measures are needed and against what species they should be directed.

The results of the survey indicated that the cabbage looper, several species of Agrotinae, and the cabbage webworm were the insects most abundant on the fall-grown crops, with their infestation peaks coming during the latter half of September and the first half of November. On the spring-grown crops the diamondback moth, the cabbage looper, and the imported cabbageworm were the most numerous, in the order named. The diamondback moth was most abundant during the first week of May, and the other two species were numerous throughout that month. All the species mentioned were found in limited numbers during midsummer on the few cabbage and collard plantings then present. The cabbage looper and the diamondback moth occurred on commercial cabbage plantings throughout the winter months, but in greatly reduced numbers after the weekly mean temperatures fell below about 50° F. Caterpillar populations then remained at a comparatively low level until after weekly mean temperatures were consistently above 60°, which usually occurred after the last week in March.

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Longevity of Parathion and Related Insecticides in Spray Residues[1]

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Parathion was first distributed as an experimental insecticide in this country in February of 1947. King and Hutson (1948 and 1949) demonstrated the rapid loss of parathion residues from apples. Hamilton (1948) showed that, when parathion was applied to pear trees for control of the pear psylla, *Psylla pyricola* Foerst, the fruit and foliage lost approximately 75 per cent of the parathion residue during the first 7 days. Snapp (1949), Ginsburg *et al.* (1950), Decker *et al.* (1950) and Westlake & Fahey (1950) similarly demonstrated the dissipation of parathion from spray residues on the fruit and foliage of miscellaneous crops. The rapid dissipation of parathion from spray residues is a definite advantage when considered from the viewpoint of residues on harvested crops, but a disadvantage from the viewpoint of residual action of the toxicant in insect control.

Since 1947 two chemicals closely related to parathion, methyl parathion and EPN, have been distributed as experimental insecticides, and formulations of these chemicals are now being recommended for control of the same general group of insects as is parathion. These three chemicals differ but little in molecular structure. Methyl parathion has two methyl groups substituted for the ethyl groups of parathion, and in EPN a benzene ring is substituted for one of the ethoxy groups of parathion. From this similarity of structure it would be expected that these chemicals would have similar physical properties. Methyl parathion, having a lower molecular weight than parathion, would be expected to have a higher vapor pressure and therefore volatilize more rapidly. On the other hand, EPN has a higher molecular weight than parathion and would be expected to have a lower vapor pressure and volatilize less rapidly.

It is the purpose of this paper to report further studies on the longevity of parathion spray residues on apple foliage and the relative longevity of parathion, methyl parathion, and EPN residues on apple foliage and peaches. Metacide, a mixture of parathion and methyl parathion, was included in these tests.

METHOD OF SAMPLING.—Foliage samples consisted of four 25-leaf replicates, one taken from each side of single-tree plots. These samples were taken from the ground level at random so that foliage in both protected and unprotected areas of the tree was included. The samples were carefully weighed within an hour after their removal from the tree, and the residues calculated to parts per million by weight. Mature apple foliage was found to contain approximately 50 square centimeters of leaf per gram; thus 100 parts per million would approximate 2 micrograms per square centimeter of leaf.

Fruit samples consisted of duplicates of 15 to 25 peaches each, depending upon the size (either 25 fruit or a sufficient number to fill a 1-gallon jar). The fruit was also taken at random from the ground level.

Chemical Analysis.—The Averell-Norris (1948) method for the analysis of parathion was employed for the analyses of all samples. In the analyses of methyl parathion and EPN residues purified samples of these chemicals were used as reference standards.

PARATHION RESIDUES ON APPLE FOLIAGE.—The rate of loss of parathion from spray residues demonstrated by various investigators suggests that significant changes in parathion concentration in residues may take place within the first few hours after a spray application. To study this possibility, on June 6, 1949, a single apple tree was sprayed with a suspension containing 3 pounds of 25 per cent parathion wettable powder to 100 gallons of water, and 1 hour later, when the foliage had dried, a foliage sample was taken for residue analysis. The analysis of this sample indicated a deposit of 736 parts per million of parathion 1 hour

[1] Presented at the meeting of the American Association of Economic Entomologists, Cincinnati, Ohio, December 10–13, 1951.

[2] Mr. Rings is employed cooperatively by the Bureau of Entomology and Plant Quarantine and the Ohio Agricultural Experiment Station, Wooster, Ohio.

after application, or approximately 15 micrograms per square centimeter of leaf. Sampling was repeated at 2 and 10 hours and after 1, 2, and 4 days. During the period of study the average daily temperature ranged from 61.2° to 83.4° F., and there was no rainfall.

In figure 1 the per cent of parathion residue retained after each sampling is plotted against the log of time. The close approximation of the points on the curve to a straight line indicates that, in the absence of rainfall and during a period of uniform temperatures, the loss of parathion from deposits is a function of the log of the time elapsed. This figure also emphasizes the very rapid loss of parathion from a deposit.

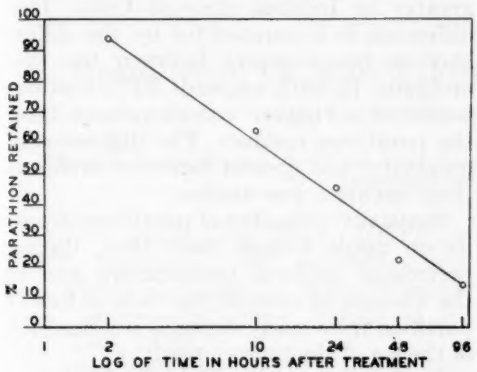

FIG. 1.—Per cent of parathion residues retained on apple foliage, 1949.

RESIDUES OF PARATHION AND RELATED INSECTICIDES ON APPLE FOLIAGE.—In 1950 a study was made of the longevity of residues on apple foliage resulting from the application of the following insecticides (quantities per 100 gallons):

Parathion 15% wettable powder, 3 pounds.
Methyl parathion 35% and Triton X-100 3% in xylene, 1 pint.
Metacide, 1 pint.
EPN 25% wettable powder, 1.5 pounds.

A single tree was sprayed with each insecticide on June 8, July 12, and September 18. The sprayed trees were separated by at least two rows of unsprayed trees. Foliage samples were taken for residue analyses as soon as the spray had dried and 1, 2, 4, 7, and 14 days after each application. The average daily temperature and total accumulated rainfall for the three periods of study were as follows:

Date	*Temperature* (°F.)	*Rainfall* (*inches*)
June 8	65.6–81.4	3.39
July 12	67.5–82.8	2.61
Sept. 18	57.8–73.8	3.10

Table 1 shows the initial deposits of these insecticides on apple foliage and the percentages of these deposits retained during the three study periods. Figure 2 demonstrates graphically the relative persistence of the four toxicants in the residues. Metacide and methyl parathion show poorer retention than parathion during the first 4 days of weathering, but

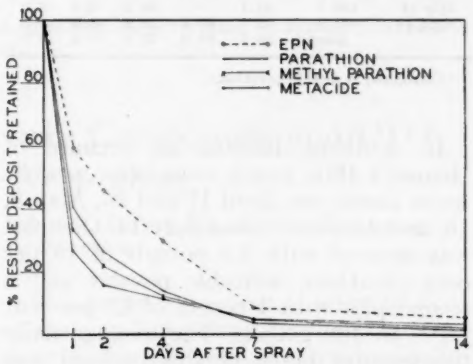

FIG. 2.—Longevity of parathion, methyl parathion, and EPN residues on apple foliage, 1950.

the differences after 7 and 14 days are negligible. On the other hand, the longevity of EPN in spray deposits is greater than that of parathion.

RESIDUES OF PARATHION AND EPN ON PEACHES.—Experiments for control of peach insects afforded an opportunity for comparing the longevity of parathion and EPN residues on peaches. Two orchards, one in northern Ohio and the second in southern Indiana, were used in this study. The variety of fruit, weather conditions, and spray treatment were different in each orchard.

In an orchard in northern Ohio Elberta peaches were sprayed three times—on July 5 and 21 and August 10. One plot was sprayed with 2 pounds of 15 per cent parathion wettable powder and a second plot with 1 pound of 25 per cent EPN to 100 gallons. The average daily temperature range in this orchard was 59.9°–77.8° F. during the period of study, and the total rainfall was 5.7 inches.

Table 1.—Residues of parathion and related insecticides retained on apple foliage, 1950.

Date of Application	Initial Deposit (p.p.m.)	Per Cent of Initial Deposit Retained After 1 Day	2 Days	4 Days	7 Days	14 Days
		Parathion				
June 8	250.2	37.2	26.8	13.2	—	1.9
July 12	144.5	44.1	—	21.7	3.5	1.5
Sept. 12	156.2	39.2	25.3	6.7	3.9	2.7
	Average	40.1	26.1	13.9	3.7	2.0
		Methyl parathion				
June 8	138.1	30.1	29.5	12.3	—	3.6
July 12	132.7	31.6	—	12.7	4.1	2.1
Sept. 12	72.2	39.0	19.0	10.9	5.3	4.6
	Average	33.2	24.3	12.0	4.7	3.4
		Metacide[1]				
June 8	216.8	24.6	16.7	13.3	—	1.8
July 12	166.8	24.3	—	9.5	4.6	1.5
Sept. 12	108.2	30.9	14.9	10.4	4.8	3.1
	Average	26.7	15.8	11.1	4.7	2.1
		EPN				
June 8	258.5	60.4	61.7	43.9	—	8.4
July 12	262.7	55.1	—	32.6	8.6	3.0
Sept. 12	235.2	63.7	29.5	12.8	8.2	5.8
	Average	59.7	45.6	29.8	8.4	5.7

[1] Calculated as methyl parathion.

In southern Indiana an orchard of Henner's Hale peach trees was sprayed seven times—on April 17 and 26, May 8, 16, and 25, June 7, and July 14. One plot was sprayed with 1.5 pounds of 15 per cent parathion wettable powder and a second plot with 1 pound of 25 per cent DPN to 100 gallons. The average daily temperature range in this orchard was 66.1°–81.6° F. during the period of study and the total accumulated rainfall was 3.3 inches. In both orchards samples of peaches were collected for residue analysis on the day of the last spray application and at various intervals thereafter, for 29 days in Ohio and 36 days in Indiana.

Table 2 shows the results of these analyses. The initial deposits of parathion in the two orchards show a close agreement when the difference in dosage is taken into account. On the other hand, the EPN residue on peaches from Ohio was four times as great as on peaches from Indiana. This difference may be partially accounted for by the additive effect of three sprays applied over a 36-day period in Ohio. The final residues in Indiana were very low, less than 0.1 ppm. of parathion and only 0.12 ppm. of EPN. The peaches from the Ohio orchard carried 0.2 ppm. of parathion and 1.5 ppm. of EPN in the final sample.

Figure 3, showing the per cent of initial deposits retained on peaches from these plots at various sampling dates, permits a rapid comparison of the longevity of

Table 2.—Parathion and EPN residues (ppm) on peaches in two orchards, 1950.

Days After Spray	Northern Ohio		Southern Indiana	
	Parathion	EPN	Parathion	EPN
0	4.3	8.3	3.03	2.05
1	4.1	7.9	—	—
2	2.9	8.2	—	—
3	—	—	0.68	0.64
4	2.6	7.8	—	—
7	—	—	0.19	0.38
8	1.6	5.6	—	—
14	—	—	0.17	0.40
15	0.8	2.9	—	—
27	—	—	0.04	0.14
29	0.2	1.5	—	—
36	—	—	0.03	0.12

parathion and EPN residues in these two orchards. The rate of loss was much greater in Indiana than in Ohio. This difference is accounted for by the difference in temperatures between the two orchards. In both orchards EPN residues persisted at higher concentrations than the parathion residues. The difference in longevity was greater between orchards than between insecticides.

SUMMARY.—Studies of parathion deposits on apple foliage show that, during periods of uniform temperature and in the absence of rainfall, the rate of loss of parthion from spray deposits is a function of the log of the time elapsed.

In a comparison of the longevity of parathion, methyl parathion, Metacide, and EPN in spray deposits on apple foliage, EPN was dissipated less rapidly than parathion, parathion was lost less rapidly than methyl parathion or Metacide during the first 4 days of weathering, but

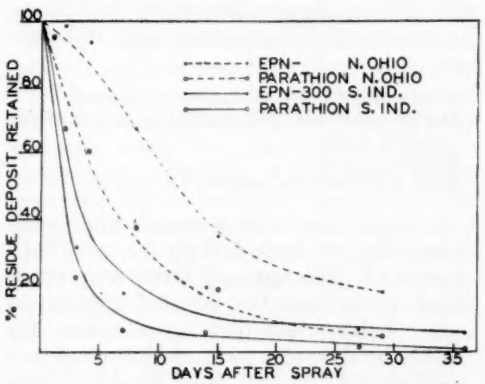

FIG. 3.—Longevity of parathion and EPN spray residues on peaches in two orchards, 1950.

there was no difference in retention after 7 days of weathering.

On peach fruits the rate of loss of parathion and EPN was much greater in southern Indiana than in northern Ohio. Although the persistence of EPN was greater than that of parathion, the difference between the two widely separated orchards was greater than between insecticides.

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Residues of Organic Phosphorus Compounds and DDT on Greenhouse Vegetables

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Aerosols containing DDT, HETP or TEPP, parathion, and sulfotepp have been widely used against pests of greenhouse ornamental crops (Smith *et al.* 1947, 1948, 1950).

In 1948 HETP or TEPP was first generally used on greenhouse tomatoes and cucumbers for the control of spider mites, white-flies, and aphids, whereas DDT was used for the control of thrips, the tomato pinworm, *Kieferia lycopersicella* (Busck), the corn earworm, *Heliothis armigera* (Hbn.), and cucumber beetles. Because parathion was highly effective against these pests and also against many other insects attacking greenhouse vegetable crops, the growers began using this chemical as an all-purpose pesticide. Later sulfotepp was also used to some extent because of its effectiveness against whiteflies and aphids.

Although many investigations on parathion residues on orchard and vegetable crops have been reported (Decker *et al.* 1950, Ginsburg *et al.* 1950; Hamilton 1948; King & Hutson 1948, 1949; Snapp 1949; and Sloan *et al.* 1951), none on residues of parathion, sulfotepp, or DDT on greenhouse vegetables have come to the writers' attention.

This paper is a report of investigations on residues from aerosol and soil applications of parathion and of aerosols of sulfotepp and DDT that were conducted in greenhouses at Beltsville, Md., since 1948. Tests were made on both spring and fall crops of wilt-resistant strain No. 5 of Globe tomatoes, White Spine cucumbers, and Grand Rapids leaf lettuce. The crops were grown in ground beds, the vine crops being supported by stakes as in commercial greenhouses.

METHODS.—Parathion in aerosols was applied at the recommended rate of 1 gram per 1000 cubic feet of space, while DDT and sulfotepp in aerosols were applied at a 0.5-gram dosage, all in greenhouse units of 7000 cubic feet capacity and 750 square feet of surface area. At the 0.5-gram dosage the deposit was 4.67 mg. per square foot or 7.17 ounces per acre.

Usually the aerosols were applied at dusk when the ventilators were closed and were left until morning for an exposure period of 12 to 15 hours. In certain tests the applications were made during the day and the ventilators were opened after 2 or 4 hours.

Parathion in a 25-per cent wettable

powder was also applied to the soil beneath a mulch on the bed surface and was worked into the upper inch of soil. Dosages were those recommended for control of garden centipedes (Thomas 1949) and also higher ones approaching the limit tolerated by the plants.

For purpose of analysis 20 clusters of tomatoes with fruits of similar size and development were selected in various parts of the greenhouse. One fruit from each of 10 clusters was collected on each sampling date. Cucumber fruits for analysis were at the slicing stage. Lettuce plants selected for uniformity were at the marketable stage when harvested except in two tests when immature plants were selected.

Parathion residues were determined in all tests by the colorimetric procedure of Averell & Norris (1948). The parathion-treated samples were macerated in a blender before extraction. Sulfotepp residues were determined by the cholinesterase inhibition method of Giang and Hall (1951), and DDT residues by total-chlorine analysis.

PARATHION RESIDUES FROM TRANSLOCATION.—Two experiments were conducted to determine the possibility that parathion might accumulate in the fruits from foliage or soil applications.

In the first experiment clusters of tomato fruits were protected from direct exposure to parathion aerosols with cellophane bags that were tied in place after pollination or when the fruits were small. These bagged fruits on plants subjected to 4 to 8 biweekly applications of aerosol showed less than 0.1 p.p.m. of parathion, an indication of no appreciable translocation. However, unprotected fruits of the same age showed a parathion content as high as 2.36 p.p.m. (Table 1). The higher residues on unbagged fruits are correlated with the interval between sampling and the last application rather than with the increased number of applications.

Table 1.—Parathion residues in bagged and unbagged fruits of tomato from plants treated with aerosols. Fall crop 1948.

NUMBER OF BIWEEKLY APPLICATIONS	INTERVAL LAST APPLICATIONS TO HARVEST	PARATHION RESIDUES	
		Bagged	Unbagged
	Days	*P.p.m.*	*P.p.m.*
Clusters bagged after pollination			
4	14	0.03	0.14
8	3	0.07	2.36
Clusters bagged when fruits were 0.5 inch in diameter			
5	6	.08	1.05

In the second experiment parathion in a 25-per cent wettable powder was applied beneath a manure mulch and was worked into the upper inch of soil. After the mulch had been replaced, no odor of parathion was detected in the greenhouse. The maximum residues found in harvested tomatoes and cucumbers (Table 2) indicated no translocation from the soil applications whether the rate was the same or higher than that recommended for the control of garden centipedes.

RESIDUES FROM DIRECT APPLICATION. —*Parathion Residues on Tomato and Cucumber.*—The residues found on fall and spring crops of tomatoes and cucumbers after biweekly applications of parathion aerosols, as are used in commercial greenhouses, are given in table 3. Smaller residues found on cucumbers were probably due to the larger volume of fruits in relation to the surface area. Higher initial and more persistent residues were found on the fall crops of tomatoes than on the spring crops. This may be correlated with low temperatures in the greenhouse. Night temperatures for the fall crop of 1948–49 were lower (60 to 65° F.) than for the fall crop of 1949–50 (70°), owing to an improvement in the heating system. Spring crops were grown at higher temperatures as the season advanced.

In one test wiping fruits with a soft cloth, as is sometimes done commercially to remove bordeaux-mixture stains, did

Table 2.—Parathion residues in tomatoes and cumcumbers from plants growing in soil treated on February 16, 1949. Spring crop.

SOIL PARATHION IN POUNDS PER ACRE	INTERVAL APPLICATION TO HARVEST	PARATHION RESIDUES
	Days	*P.p.m.*
Tomatoes		
8	76	0
64	76	.01
128[1]	28	.01
Cucumbers		
8	85	.02
64	85	0

[1] 64 pounds applied on February 16 and May 11.

Table 3.—Parathion residues on tomatoes and cucumbers after applications of aerosols.

NUMBER OF BIWEEKLY APPLICATIONS	INTERVAL LAST APPLICATION TO HARVEST	PARATHION RESIDUES	
		Tomatoes	Cucumbers
	Days	*P.p.m.*	*P.p.m.*
	Fall Crop 1948–49		
4	14	0.14	—
5	6	1.05	0.11
8	3	2.36	.20
9	1	2.51	—
	5	2.28	—
	12	.36	—
	Spring Crop 1949		
4	12	.23	—
5	2 hours	1.17	.62
	3	.68	.17
	6	.42	—
	14	.19	—
6	1 hour	.97	.15
	7	.39	.01
	14	.18	.00
	Fall Crop 1949–50		
1	0	1.59	.16
	2	1.36	—
	5	1.19	—
	11	.51	—
2	0	2.21	—
	2	1.96	—
	6	1.03	—
	13	.83	—
	14	.54	—
3	0	1.32	—
		1.66[1]	—

[1] Fruits wiped with cloth.

not reduce the parathion residue (Table 3).

In 1950 foliage and fruits from the same tomato plants were analyzed for residues. Higher residues were found on the leaves (Table 4). This was to be expected because for the same surface areas leaves have much less bulk and weight than do fruits.

In these studies it is evident that parathion residues did not accumulate with repeated applications at biweekly intervals. This interval allowed time for practically complete subsidence of the residue.

In an experiment to build up a maximum residue of parathion by the aerosol method, nine applications were made to tomato plants at 3- to 4-day intervals between January 26 and February 19, 1950. In this experiment parathion, 63 grams, was applied. This is equivalent to 14.34 ounces per acre-application, or a total of approximately 8.1 pounds within the 24 days. The night temperatures were 70°F. and day temperatures sometimes

Table 4.—Parathion residues on foliage and fruits of tomatoes after three biweekly applications of aerosols. Spring crop 1950.

INTERVAL LAST APPLICATION TO HARVEST	PARATHION RESIDUES	
	Fruits	Foliage
Days	*P.p.m.*	*P.p.m.*
0	0.68	21.53
4	.51	2.66
7	.47	1.91
11	.20	1.24
14	.14	1.56

reached 92°. Analyses of tomato fruits collected immediately after the ninth application and again 9 days later indicated an initial high but a rapidly declining parathion residue (Table 5).

Parathion Residues on Lettuce.—Results of tests for residues of parathion on three crops of leaf lettuce are given in table 6. The initial residue was higher on immature than on mature plants. The young plants covered the same surface area but weighed only one-fourth as much.

In the spring of 1951 the groups of plants selected at the first sampling averaged 110 grams when the residue was 34 p.p.m. At the last sampling 24 days later the average weight was 332 grams per plant, but the residue was only 0.1 p.p.m. of parathion. Greater losses were therefore due to weathering than to reduction in p.p.m. by weight increases.

Sulfotepp Residues on Lettuce.—The results of tests with sulfotepp on the same three crops of leaf lettuce but in separate greenhouse units are also given in table 6. Generally the deposit of sulfotepp was somewhat lower but persisted to about the same degree. The persistence of sulfotepp residues for several days on the basis of chemical analyses does not agree with its toxic effect on insects that persist for only a few hours (Smith & Fulton 1950).

The loss of sulfotepp residues on lettuce of the spring-1951 crop, like parathion, was due mostly to weathering. The last

Table 5.—Parathion residues on tomatoes after nine aerosol treatments between January 26 and February 19, 1950.

TOMATOES COLLECTED	INTERVAL AFTER LAST TREATMENT	PARATHION RESIDUE	
		Treated	Check
	Days	*P.p.m.*	*P.p.m.*
Feb. 20	0	10.24	0.22
Mar. 1	9	3.92	.17

Table 6.—Residues on leaf lettuce treated with parathion and sulfotepp aerosols.

Interval between Treatment and Sampling (Days)	Parathion Residues		Sulfotepp Residues	
	Fall 1950	Spring 0951	Fall 2950	Spring 1951
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*
	Immature plants			
1 hour	97.8	—	91.6	—
3	83.5	—	38.5	—
7	26.7	—	12.6	—
10	11.9	—	8.6	—
14	6.1	—	5.8	—
20	2.0	—	3.0	—
	Mature plants			
1 hour	56.0	34.0	40.9	35.0
3	9.4	14.0	13.8	10.8
6	—	6.4	—	3.0
7	6.1	—	—	—
9	—	3.1	—	1.1
10	—	—	6.6	—
13	—	1.0	—	.6
07	.7	.7	2.3	—
24	—	.1	—	—

Table 7.—Sulfotepp residues on lettuce and tomato. Spring 1950.

Date Collected	Interval After Treatment	Sulfotepp Residue		
		Lettuce Leaves	Tomato Foliage	Tomato Fruits
	Days	*P.p.m.*	*P.p.m.*	*P.p.m.*
May 8[1]	0	10.1	—	—
10	2	6.8	—	—
12	4	2.6	—	—
15	7	.3	—	—
June 6[1]	0	—	2.4	.01
9	3	—	2.9	.02
12	6	—	.7	.01
16	10	—	.3	.01 or less
20	14	—	.2	.01 or less
28[2]	0	—	8.24	.55
29	1	—	6.92	.03
July 3	5	—	1.85	.04
6	8	—	.35	.03

[1] Immediately after one application.
[2] After three applications, on June 6, 19, and 28.

sample of plants collected 13 days after the first was only 2.2 times heavier, yet the sulfotepp declined from 35 to 0.6 p.p.m.

In the spring of 1950 lettuce and tomato treated with sulfotepp were analyzed for residues. In all tests the parathion and sulfotepp residues on lettuce were higher than on tomato foliage or fruits and they persisted longer after a single treatment (Tables 4, 6 and 7). As with parathion (Table 4), less sulfotepp was found on tomato fruits than on the foliage. The decrease of sulfotepp residues on the tomatoes in this experiment (Table 7) appeared to be more rapid than that of parathion residues (Table 4).

DDT Residues on Tomato.—An experiment was conducted to determine the DDT residues on tomatoes after applications of DDT aerosol as used for the control of thrips and tomato pinworms. On January 26 and again on February 19, 1950, the aerosol was applied to tomatoes and samples were harvested immediately after each application. A residue of 0.5 p.p.m. was found after the first application and 1.06 p.p.m. after the second. The greater residue suggests an accumulation of DDT by repeated applications.

SUMMARY.—To secure information on the effect on vegetables of chemicals applied in the greenhouses as required for pest control, investigations were carried out at Beltsville, Md., from 1948 through 1951. Aerosols at the rate of 1 gram of parathion per 1000 cubic feet, or sulfotepp or DDT at half this rate, were applied to tomatoes, cucumbers, and lettuce.

Parathion was added to soil, in which tomatoes were grown, at rates of 8 to 128 pounds per acre. Parathion residues were determined by the colorimetric procedure, sulfotepp by the cholinesterase inhibition method, and DDT by total-chlorine analysis.

In experiments on possible translocation of parathion, clusters of tomatoes, bagged after pollination or when fruits were small, contained no appreciable amounts of parathion when harvested. Unbagged fruits on the same plants contained a maximum of 2.36 p.p.m. Parathion was not translocated from treated foliage to bagged tomato fruits or from treated soil to fruits.

Residues of parathion on tomato decreased after each biweekly application and no accumulated residue was evident after the ninth application. However, when nine applications were made within 24 days the accumulated residue was 10.02 p.p.m., or about four times the maximum from any single application.

The maximum parathion residue on tomato fruits was 2.51 p.p.m. on the day after treatment, the maximum after 3, 5, 7, 11 and 14 days, respectively, 2.36, 2.28, 0.47, 0.51 and 0.14 p.p.m. On cucumber fruits maximum residue was 0.62 p.p.m. On tomato foliage the maximum residue of parathion was 21.53 p.p.m., which decreased to 1.56 p.p.m. in 14 days. On lettuce the residues ranged from 34 to 56 p.p.m. immediately after treatment in two experiments and decreased to 0.7 p.p.m. in 17 days and in a third experiment the original residue of 97.8 p.p.m. decreased to 2.0 p.p.m. in 20 days.

Residues of sulfotepp were generally somewhat lower than parathion on tomato fruits or foliage or on lettuce. However, the residues of the two materials decreased at approximately the same rate, although the insecticidal action of sulfotepp was short.

The results indicated a low residue of parathion on cucumbers and a maximum residue of parathion and sulfotepp on tomatoes which declined within 7 days below 1 p.p.m. The excessive residues on lettuce and their persistence for about 3 weeks indicate that these materials could not be safely used on leaf lettuce in greenhouses except possibly in the early stages of growth.

Residues of DDT on tomato fruits ranged from 0.5 to 1.06 p.p.m. after one and two applications.

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Early Spray Applications to Control Alfalfa Weevil

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Several problems have arisen as a result of the greatly increased usage of insecticides when applied in the early spring for alfalfa weevil control. Among these problems are the questions of how early in the spring control measures can be used, and how low a dosage of dieldrin would still produce the desired results. At what stage of growth of the alfalfa is this early method of control no longer effective, was also of interest. It was likewise desirable to know whether or not oviposition occurred in sufficient quantity in dead stems to affect control if alfalfa growth is retarded and spraying delayed until new growth begins. Specific data on spray residues at the time of first cutting when fields were treated with dieldrin at an early stage of growth were also needed.

The short period of time in which insecticides can be applied effectively has resulted in a great deal of aircraft application. Previous tests by Hastings & Pepper (1951) have shown this means of application of insecticides for alfalfa weevil control to be equally as effective as ground-rig spraying. However, the cost of application by aircraft is somewhat of a limiting factor in many cases. If a total volume of carrier (diesel oil) of less than 2 gallons per acre or a dosage of less than 4 ounces of dieldrin per acre would remain effective, this cost could be materially reduced. The following work was undertaken to provide information on the above mentioned problems.

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Table 1.—Per cent reduction in alfalfa weevil population (using ground sprayer).

Date of Inspection	Per Cent Adult Reduction						Per Cent Larval Reduction		
	May 24, 1951			June 18, 1951			June 18, 1951		
	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
Date of Spraying	4/4/51	4/12/51	4/26/51	4/4/51	4/12/51	4/26/51	4/4/51	4/12/51	4/26/51
Field No. 1	94	95	95	88	94	94	99	98	76
Field No. 2	94	98	94	88	88	71	98	92	59
Field No. 3	84	94	87	13	68	84	90	97	94
Average	91	96	92	63	83	83	96	96	76

To obtain quantitative data on the effects of applying the insecticide at different stages of growth, tests were conducted on three different alfalfa fields in the same general locality. Each field was divided into four plots of approximately 10 acres each. One application of 4 ounces of dieldrin per acre as an emulsion was made on each treated plot using a ground sprayer which was calibrated to deliver a total volume of 10 gallons per acre. The first plot in each field was treated before any new spring growth was evident. The second and third plots in each field were treated 8 days and 22 days, respectively, after the first plot was sprayed. The fourth plot in each field was utilized for comparison and was left untreated.

In two of the fields (No. 1 and No. 2), there was 1 to 2 inches of new spring growth at the time the second plots were sprayed and 3 to 5 inches of new growth when the third plots were treated. Field No. 3. did not show any evidence of early spring growth until the last plot was sprayed, 22 days after the first one in this field was treated.

A comparison between the treated and untreated areas in a field was obtained by making adult and larval population counts 7 and 11 weeks after treating the first plot. The alfalfa weevils obtained by taking one hundred 180 degree sweeps from each plot served as the basis for comparison. These data are presented in table 1.

Population counts are not included because they can be used only as a basis of comparison in a single field. There is frequently an extreme difference in degree of larval infestation between fields. Also, there are the inevitable differences in conditions which affect population counts (physical factors, stand, height, etc.) at the time of sampling. That these differences exist is evidenced by the fact that larval counts in check plots in the several fields used in this work varied between 300 and 13,000 per hundred sweeps. The same situation exists relative to adult counts where conditions of air temperature and alfalfa growth, etc., are known markedly to affect adult activity (Sweetman (1929)). Gray & Treloar (1933) concluded from sampling for freely moving insects in a very uniform community, an alfalfa field, that the number of sweeps would have to be of the order of 3,000 to over 25,000 to give results accurate to within 10 per cent of the mean 95 per cent of the time. While alfalfa weevil larvae may not be considered freely moving, the adults could very well fit this category.

The data show that it is not necessary to apply dieldrin on new green foliage to affect the control of adult alfalfa weevils. Complete protection was obtained in plot 1 of each field where, in all cases, the fields were completely barren of new growth at the time of spraying. It is apparent, although there is a limit beyond which adequate larval control is not obtained, that delayed spraying is still effective in killing adult weevils. There is also evidence to confirm a previous impression that egg deposition is largely limited to green growth. It will be noted that, in Field No. 3, Plot 3, complete larval control resulted even when this plot was sprayed as late as April 26, at which time alfalfa growth was just beginning. In the other two fields, where the new growth of alfalfa was 3 to 5 inches in height, satisfactory control was not obtained on plots 3 which were also sprayed on April 26. Heavy larval popu-

lations were found in the check plots of all three fields.

The data presented in the several tables show that reduction in adult beetle populations is somewhat erratic. This may have been due to adult migrations in local areas. However, in all the tests reported in this work as well as in previously conducted tests, when dosages of effective insecticide were applied, before the new growth of alfalfa was 3 inches high, uniformly effective larval control resulted. It is believed that conditions in Montana do not become right for appreciable adult migration until too late in the spring for the eggs, which are later deposited, to hatch before the first cutting is removed.

It should be noted that a flight of adult weevil was observed on the afternoon of April 26 throughout the area where tests were being carried on. The beetles were extremely numerous in the air and appeared to be hovering between 8 and 10 feet above the ground. In several years of working with this insect, adult flight had not been previously observed, although it had been reported by farmers. Cooley (1912) reported a "spring flight" and a "summer flight" in Montana. Sweetman (1929) working in Wyoming observed no adult flights during May, June, or July in 1927, 1928, and 1929. He further states that flights may have taken place during August and September as only a few observations were made during these months.

The foregoing tests show that there is a period of from 2 to 3 weeks in the early spring, under Montana conditions at least, when completely effective control of larval populations can be obtained by early spraying to kill the adults. Later spraying, when the alfalfa has attained a growth of approximately 3 to 5 inches, results in partial larval control, not sufficiently effective, however, to prevent some visable damage to first cutting growth.

The results of these tests indicate that effective control can be obtained by spraying as early in the spring as it is possible to use equipment in the fields. The longer spraying is delayed the greater becomes the probability that complete control will not be obtained.

That considerable retardation of second growth is experienced in untreated fields, is evident from the following measurements. Field 2 was observed again on July 17, 27 days after harvest of first cutting. The untreated check plot had 0 to 4 inches of new growth; whereas plot 1, sprayed on April 4, had 20 to 24 inches, and plot 3, sprayed on April 26, had between 16 and 19 inches of new growth. Field 1 was observed July 19, 29 days after harvest of the first cutting. The untreated check plot had 5 to 7 inches of new growth at this time with considerable damage being evident to second growth foliage; whereas, the plot sprayed on April 4 had 20 to 24 inches. While visable damage to first cutting foliage was apparent on these two plots sprayed on April 26, and while the per cent larval reduction was somewhat less than on the plots sprayed earlier, there was still considerable benefit derived from these later sprayings.

Further studies were undertaken to establish a minimum dosage of dieldrin that would be effective in adult weevil control. Three alfalfa meadows were obtained each of which could be divided into three 10 acre plots. One plot in each field was sprayed with a dieldrin emulsion at the rate of 2 ounces of dieldrin in 10 gallons of water per acre, using 35 pounds boom pressure. A second plot in each field was sprayed with 3 ounces of diel-

Table 2.—Per cent reduction in alfalfa weevil populations (using ground sprayer).

	Per Cent Adult Reduction				Per Cent Larval Reduction	
Date of Inspection	May 24, 1951		June 18, 1951		June 18, 1951	
Plot—Dosage	Plot 1 (2 Oz./Acre)	Plot 2 (3 Oz./Acre)	Plot 1 (2 Oz./Acre)	Plot 2 (3 Oz./Acre)	Plot 1 (2 Oz./Acre)	Plot 2 (3 Oz./Acre)
Field No. 1	55	81	0	58	89	84
Field No. 2	0	54	16	59	81	95
Field No. 3	0	74	—	—	—	—
Average	18	70	8	59	85	90

drin per acre in the same manner as described above, and a third plot in every meadow was left untreated to serve as a basis of comparison. The fields were treated on April 7 as new green growth was just beginning to show.

Population counts were made, as previously described, on May 24, for adults and on June 18, for both adults and larvae. This latter date was just before harvesting the first cutting. The percentage reduction in populations in the treated plots is presented in table 2. Field 3 was cut before the June 18 samples could be obtained.

It is apparent from the data in table 2 that a very marked reduction in larval populations is obtained even at dosages as low as 2 ounces of dieldrin per acre. Measurements also showed that no appreciable retardation of second growth was experienced with this low rate of application. Sufficient larval populations, however, did develop, with the exception of the 3 ounce application in field 2, to cause moderate foliage damage on first cutting forage. Field 3 of this series of tests was harvested on June 8. It was observed on June 19, 11 days after the first cutting. The untreated check was still devoid of new growth; while, the area treated with 3 ounces of dieldrin had 9 inches at this time. On July 16, 38 days after the first cutting, there was 24 to 26 inches of new growth on the treated area and 9 to 10 inches on the untreated. Foliage damage to second growth was evident in this untreated check plot.

The data presented in table 3 are the results of tests conducted for alfalfa weevil control using aircraft to apply dieldrin at various dosage and total volume levels. Number two diesel fuel was used as the diluent. The four different meadows utilized in these tests were divided into approximately 20 acre plots, leaving one plot in each field untreated.

The fields were sprayed on dates between April 4 and April 12, 1951, depending on their stage of growth. In all cases application was made when the alfalfa was just beginning to show new green growth. A comparison between the treated and untreated areas was made by taking sweep samples as previously described.

It will be noted from the data presented in table 3, that no close relationships were found to exist between the various levels of treatment and reduction in adult populations on the dates when adult counts were made. However, this was not the case when the fields were compared on the basis of larval populations just prior to harvest. The data show that a reduction in dosage of toxicant had less effect in resultant larval control than a reduction in total volume of diluent had. In these tests both the 2 and 3 ounce per acre dosages, in a total volume of 2 gallons, gave excellent control. Four ounces of toxicant in total volumes of both 1 and 1.5 gallons per acre did not give satisfactory commercial control in all cases. It would appear that a total volume of less than 2 gallons is inadequate to insure complete coverage.

It should be pointed out that where alfalfa weevil is concerned, satisfactory commercial control frequently means virtually complete control. Usually the alfalfa grower does not have the time or

Table 3.—Per cent reduction in weevil population at various total volume and dosage levels (using aircraft).

	Per Cent Adult Reduction								Per Cent Larval Reduction			
Date of Inspection	May 22, 1951				June 18, 1951				June 18, 1951			
Dosage Levels (Ounces/Acre)	3	2	4	4	3	2	4	4	3	2	4	4
Total Volume (Gallons/Acre)	2	2	1	1.5	2	2	1	1.5	2	2	1	1.5
Field No. 1	78	92	—	67	93	85	—	79	99	98	—	96
Field No. 2	95	79	—	—	69	90	—	—	98	97	—	—
Field No. 3	51	—	70	76	76	—	71	37	95	—	86	90
Field No. 4	—	—	80	88	—	—	74	75	—	—	78	92
Average per cent	71	85	75	77	80	88	74	66	79	98	82	93

facilities to arrive at a percentage figure representing degree of control and then to base his level of satisfaction on this figure. Experience has shown that if visable damage is present on first cutting forage, the alfalfa grower is dissatisfied.

Field 1 in the series of aircraft tests was harvested on June 25. It was observed on July 16, 21 days after harvest, at which time there was 12 to 20 inches of new growth on the plot treated with 4 ounces of dieldrin and 1.5 gallons of oil per acre and 0 to 2 inches of new growth on the untreated area. This field was again observed on August 8, 44 days after the first cutting. The same treated plot was 30 to 35 inches high and in nearly full bloom while the check plot was 20 to 25 inches high with no bloom evident. In the other two plots, sprayed at the same rate, there was visible damage to first cutting foliage even though a marked reduction in larval populations was recorded.

A comparison of the results reported in tables 2 and 3 show that a greater percentage reduction was obtained in larval population in both the 2 and 3 ounce per acre applications by airplane than by the use of ground equipment. Oral communications from several sources have been obtained to the effect that in grasshopper control work, greater residual action can be expected from oil solutions than water emulsions of dieldrin. The fact that a greater per cent reduction in adult populations was obtained by aircraft application, as evidenced on both dates of inspection, may be an indication of greater residual action on the part of the oil solution.

Samples of first cutting alfalfa were taken from several plots in the fields sprayed with aircraft. These samples were randomly selected, and were obtained by clipping individual stems at the crown. They were taken from untreated as well as treated plots, and were obtained 10 weeks after the spray had been applied and just previous to harvest.

Two hundred gram samples of freshly cut alfalfa were extracted in 400 ml. of thiophene-free benzine and filtered. The filtrate was forwarded to the technical service laboratory of Julius Hyman and Company, Denver, Colorado, where bioassays were conducted. The results of these bioassays indicate that at the dosages of 2, 3, and 8 ounces per acre, no dieldrin residues were detected. The dosage of 8 ounces per acre is twice the dosage normally recommended for adult alfalfa weevil control.

SUMMARY.—The results of these tests show that adequate dosages of dieldrin applied to bare stubble previous to the appearance of new spring growth gives satisfactory alfalfa weevil larval control. Further evidence is obtained to the effect that oviposition is largely limited to green growth, and that fall or early spring egg deposition in old stubble is of minor importance. Flight of adult weevils, while observed in the spring, did not occur early enough to affect the larval population in first cutting alfalfa where early control was practiced. A marked degree of control was apparent in fields sprayed after they were 4 or 5 inches high; however, the earlier spraying was accomplished the greater the degree of control.

Dosages of 2 and 3 ounces of dieldrin per acre did not prove as effective as the 4 ounce application when applied with a ground sprayer. Airplane application using 4 ounces of dieldrin in less than 2 gallons of diluent per acre did not prove as effective as 2 or 3 ounces of dieldrin using 2 gallons of diluent per acre.

Differences in growth of second cutting between treated and untreated areas, approximately 30 days after the first cutting had been removed, were found to be from 12 to 20 inches depending upon the conditions.

First cutting alfalfa taken from sprayed plots 10 weeks after application did not show any dieldrin content in either 2, 3, or 8 ounce per acre airplane applications.

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Control of Mosquito Larvae and other Pests in Rice Fields by DDT[1]

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Many of the rice fields in the Sacramento Valley of California have been heavily infested with mosquitoes, tadpole shrimps and giant water scavenger beetles in past years. Flood water mosquitoes originating in the rice fields have constituted a serious local pest problem and have been costly to the mosquito abatement districts to control by the use of aerosols. Also many of the rice growers have experienced serious economic losses due to shrimp infestation, and to a lesser degree to giant water scavenger beetle infestation. Therefore, extended field tests involving 3910 acres of commercial rice fields in the vicintity of Biggs and Richvale, and field plots at the Biggs Rice Experimental Station, were carried out in the spring of 1950. This was made possible by the cooperation of 33 rice growers, eight airplane rice sowing services and the Board of Trustees of the Butte County Mosquito Abatement District which furnished the toxicants and permitted the use of the District's personnel and equipment.

PESTS INVOLVED.—*Aëdes dorsalis* (Meigen), a "flood water" mosquito, has become established in many of the rice fields of California. The intial flooding of a mosquito-egg-infested rice field produces a "single" brood of mosquitoes. The eggs of *Aëdes dorsalis* over-winter in the soil. Mosquito control workers in California have found that the eggs winter in the soil and that some of the eggs will remain viable in fallow fields for several years. Herms & Gray (1944) reported an account of the survival of *Aëdes dorsalis* eggs in a dry marsh for about 10 years. This species of mosquito has been a serious pest in the rice areas of California for several years. These mosquitoes, originating in infested rice fields, may disseminate throughout the surrounding area as far as 5 miles, infesting other rice fields and suitable breeding sites, and plaguing the residents of the area.

The fairy or tadpole shrimps, *Apus oryzaphagus* n. sp. and *Apus biggsi* n. sp. were first reported to be of economic importance in California rice culture by Rosenberg in 1946. Since that time these crustaceans, primarily *Apus oryzaphagus*, have been causing damage throughout the rice area of the northern Sacramento Valley. They chew off the tender leaves and dislodge the soil around the roots of the rice seedlings; the uprooted seedlings then float to the surface. The muddy water resulting from their digging activities inhibits the growth of the rice seedlings by reducing the amount of sunlight reaching the submerged seedlings. Often the shrimps appear in such large numbers and destroy so many of the seedlings that it is necessary to re-seed. The shrimp eggs remain in the soil over winter and hatch under favorable conditions when the field is flooded the following year. Rosenberg (1946) states that rice fields infested with shrimp eggs will again be infested with shrimps when flooded even though the fields have lain fallow for a year or more.

In recent years the larval form of the giant scavenger water beetle, *Hydrous triangularis* (Say) has become a pest of considerable importance in some of the California rice-growing areas. The beetle larvae do not chew off the leaves of the seedlings as do the tadpole shrimps but uproot the entire plant. They dwell on the bottom of the flooded rice paddies and by their digging activity stir up the soil causing the water in the checks to become muddy, comparable to tadpole shrimp infested waters. Beetle larvae are active during the first few weeks after flooding and are, therefore, a pest at the same time as are the tadpole shrimps.

PRESENT METHODS OF CONTROL.—The standard larviciding methods will control the *Aëdes dorsalis* larvae in the recently flooded rice fields but these methods are not satisfactory from an economic and operational standpoint for use by mosquito abatement districts. This is especially true when large acreages of infested rice fields must be treated in a

[1] Cooperative investigations of the California Agricultural Experiment Station and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture and the Butte County Mosquito Abatement District.

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short period of time in order to protect the adjacent populated areas. Therefore the authors sought a method of application and a toxicant which would not only control the shrimps as economically as copper sulfate but would also result in the effective control of the *Aëdes dorsalis* larvae. Herms & Sperbeck[1] found that wettable powder DDT, applied to seed rice as it was dumped into the plane loading-hoppers, would stick to the damp kernels. They also found that when wettable powder DDT was introduced into the flooded fields by this method that the *Aëdes dorsalis* larvae were controlled. Through a series of laboratory tests they determined that the DDT when used in amounts up to 2 pounds per acre had no effect upon the germination of the rice nor upon the growth of the seedlings.

Rosenberg (1946) found that the shrimps could be controlled in the rice fields by the application of 1 pound of copper sulfate penta hydrate per acre-inch of water, or by the application of 8 ounces of DDT as a water emulsion per acre-inch of water. The present method of shrimp control is to apply about 10 pounds of copper sulfate per acre by airplane. Usually this is done when floating rice seedlings are observed, adult shrimps are seen, or when the water appears muddy. The damage often is extensive before it is realized that the field is heavily infested.

It has been observed by workers in mosquito control that the giant water scavenger beetles are readily killed by many of the mosquito larvicidal-sprays, but the effect of these sprays on the beetle larvae was not known. Davis (1950) states that copper sulfate as used for shrimp control has no effect on the beetle larvae, also that no control for this larva has been found beyond draining the rice field. Recently some of the newer toxicants have been tried but with varying results.

METHODS.—The following methods were used in the 1950 tests:—

1. Pretreatment of the dry cultivated soil of the rice fields by use of DDT sprays prior to flooding.
2. Application of wettable powder DDT with the seed rice when sown.
3. Treatment of flooded rice fields with DDT sprays after mosquito larvae, tadpole shrimps and beetle larvae were present.

TESTS.—1. Pre-treatment of the rice field soil by spray wand and spray boom.

Pre-treatment was by means of a manually operated spray wand and a spray boom. Four adjacent plots at the Biggs Rice Experimental Station were used in this test. Three of these were 4 acres and the other was 2 acres in area.

A plot of 4 acres was pre-treated on April 26 by means of a spray boom, with an average dosage of 4.2 pounds of DDT per acre, using a DDT-xylene-water emulsion spray containing 0.4 pound of DDT per gallon.

A plot of 4 acres and a plot of 2 acres were used as untreated check plots.

A plot of 4 acres was pre-treated on April 26 partly by means of a hand operated spray wand attached to a power sprayer and partly by means of a spray boom. The dosage varied from 3 to 4 pounds of DDT per acre. The aqueous spray, containing 0.4 pound of DDT per gallon, was prepared from 50 per cent DDT wettable powder.

Flooding of the plots was started on May 4 and completed by May 6. Observations made during the following two weeks showed that no tadpole shrimps or mosquito larvae were present in any of the plots. The treated plots were almost devoid of aquatic life, particularly small fresh water crustaceans.

Bottomless cages constructed of 0.25 inch hardware cloth, 2 feet in diameter, were set 3 inches deep into the soil of the rice paddies in order to simulate natural conditions.

Large active shrimps were caught in an untreated field 3 miles distant, transported at once and placed in the cages. Twenty-five shrimps were placed in one-third of the cages on May 17, and 25 shrimps were placed in each of the remaining cages on May 18.

The shrimps remaining alive in the treated plots after 24 hours did not exhibit the destructive digging activities which are characteristic of normal shrimps.

On June 5, 40 days after pre-treatment and 30 days after flooding, anopheline and culicine larvae as well as other aquatic life was observed in all of the plots.

The results observed are listed in table 1.

[1] Herms, H., and Sperbeck, T. M. 1948. Unpublished data. Sutter-Yuba Mosquito Abatement District.

Table 1.—Mortality of caged shrimps in plots pre-treated with DDT water emulsion, and with DDT wettable powder suspension, showing live shrimps.

Days of Exposure	Emulsion 4.2 Lbs. DDT/Acre	Suspension 3 to 4 Lbs. DDT/Acre	Check
0	75	75	100
1	13	12	83
2	2	0	75
3	0	0	48
4	0	0	16
6	0	0	3
9	0	0	3

2. Pre-treatment of rice field soil by hand mist-spraying.

A series of 19 adjacent 0.1 acre plots at the Biggs Rice Experimental Station were used. Every other pair of plots was treated, the pairs of in between plots were used as untreated checks.

A dosage of 1 pound of DDT per acre, using a DDT-xylene-water emulsion spray containing 0.8 pound of DDT per gallon, was applied to 3 pairs of plots. A dosage of 8 ounces of DDT per acre, using a DDT-xylene-water emulsion containing 0.4 pound of DDT per gallon, was applied to 2 pairs of plots.

The DDT-xylene-water emulsion sprays were prepared by diluting a 25 per cent DDT-xylene-emulsible concentrate with water.

The emulsion sprays were applied, on May 8, at the rate of 1 quart per pair of plot, by means of a cylindrical, compressed air, hand sprayer, equipped with a mist spray nozzle.[5]

One cage, the same size as used in the other test, was placed in each of the 0.1 acre plots. The cages were placed at the center of the sides of the plots—one cage being on each side of the levee separating each pair of plots, so that there would be less likelihood of contamination or dilution due to water passing over the levees, or by flowing through cuts in the levees.

Water was turned into the plots on May 15 and they were completely flooded by May 18.

Twenty shrimps, obtained from the same field as in the other test, were placed in each cage on May 19. Observations made during the next 2 weeks showed that there was considerably less aquatic life in the treated than in the untreated plots.

Throughout the 19 plots water flowed through cuts in the levees from each 0.1 acre plot to the one adjoining it. Thus water entering plot 6 from the irrigation ditch flowed through plots 5, 4, 3, 2 and 1. The results of the test showed that if any DDT was transported by the slowly moving water from one plot to another, it was apparently in low enough concentration to be below the required lethal strength.

The results observed are shown in table 2.

Table 2.—Mortality of caged shrimps in plots pre-treated with DDT-water-emulsion, showing live shrimps.

Days of Exposure	1 Lb. DDT/Acre	8 Oz. DDT/Acre	Check
0	120	80	180
1	11	38	155
2	2	13	103
3	1	6	78
5	0	2	38
7	0	0	5

3. Application of wettable powder DDT with the seed rice when sown.

Using Richvale as a center, the rice fields of all cooperating growers within a mile radius were treated with approximately four pounds of wettable powder DDT per acre, and the rice fields beyond this area but within a radius of 2 miles were treated with approximately 2 pounds of wettable powder DDT per acre. The rice fields of a number of other growers in the Richvale and Biggs areas were also treated with from one to four pounds of DDT wettable powder.

The 50 per cent DDT wettable powder was distributed and mixed with the seed rice as it was dumped from the sacks into the plane-loading hopper.

It was found that: (a) When the hull of the seed rice was damp the wettable powder would form a firmly adhering coating on the seeds, and that the unloading of rice from the hopper into the plane would further distribute the wettable powder over the seeds. The powder adhered well and most of it remained on the seed until it rested on the submerged soil of the flooded field, where it was observed to mix with the water and be slightly dispersed.

The wettable powder coated seed rice

[5] Teejet No. 3 nozzle, manufactured by Spraying Systems Company.

did not flow from the plane loading hoppers as readily as the uncoated seed rice, and it was necessary in some instances to rake it out of hopper chutes manually. Also it was necessary to increase the opening of planes' discharge slots.

(b) When the hull of the seed rice was dry only a small amount of the powder would adhere to the kernels and the rest would be distributed over the field as in dusting operations. Due to the height of the plane when sowing and to the prevailing winds most of the wettable powder did not reach the rice field. In one instance a sufficient amount of 50 per cent DDT wettable powder did not reach the rice field to control the mosquito larvae present.

(c) When the seed rice was dry or more powder was added than would stick to the kernels, the back-wash from the plane's idling propeller would blow some of the loose dust out of the plane loading hopper and chute; this caused a minor discomfort to the men loading the plane.

Four weekly post-treatment inspections were made of a number of the rice fields on which wettable powder DDT had been applied with the seed rice. These inspections confirmed the reports received from the rice growers that:

(1) the shrimps, the beetles and beetle larvae, and the mosquito larvae which were in the fields at the time of sowing were effectively controlled,

(2) no shrimps nor mosquito larvae were produced within a period of about a month in any of the 3910 acres which were treated.

Subsequent random inspections and reports from the rice growers as much as 2 to 3 months since the time of treatment showed that the fields have remained free from shrimps, but larvae of *Culex tarsalis* and *Anopheles freeborni* appeared in some of the fields in small numbers.

A rice field of 200 acres was heavily infested with shrimps 5 days after flooding. The field was sown by plane without being treated with either copper sulfate or DDT. Later the field was treated with copper sulfate, but not before the shrimps had destroyed most of the seedlings. The copper sulfate killed practically all of the shrimps but did not affect the beetle larvae. When the field was re-sown, wettable powder DDT was applied to seed at the rate of 1.8 pounds per acre. The next morning all of the beetle larvae were dead; and a reinfestation of shrimps, which the owner expected, did not occur.

An unsown rice field of 92 acres infested with shrimps was treated at the time of sowing with wettable powder DDT at the rate of 3.9 pounds per acre. The shrimps, beetles and beetle larvae, and mosquito larvae were all killed. A reinfestation of shrimps did not occur, nor were mosquito larvae observed for more than 3 weeks.

4. Treatment of flooded rice fields with DDT sprays after mosquito larvae, tadple shrimps and beetle larvae were present.

An untreated field of about 70 acres, which was heavily infested with *Aëdes dorsalis* larvae and fairly heavily infested with shrimps in some of the checks, was sprayed with a DDT oil solution at the rate of 0.2 pound of DDT per acre. The spraying was done by means of a cylindrical compressed air hand sprayer and a mist spray nozzle. The DDT oil[1] solution contained 0.4 pound of DDT per gallon, 1 per cent of thiocyanate[2] and 0.5 per cent spreader[3] both by volume. An excellent kill of the mosquito larvae and pupae was obtained except for some late fourth instar larvae which were killed by subsequent spot larviciding. Some of the shrimps were killed particularly those in the shallow water at the edges of the field.

Five rice checks at the Biggs Rice Experimental Station, lightly infested with shrimps, were sprayed with a 12.5 per cent DDT-xylene type-water emulsion. Two of these checks comprising about 2 acres were treated at the rate of 1 pound of DDT per acre, and the other three checks comprising about 4 acres were treated at the rate of 8 ounces of DDT per acre. The emulsion was mist sprayed by hand using the wind to drift it out into the checks. The emulsifier-spreader[3] used in the emulsifiable concentrate formed an emulsion which spread rapidly over the surface of the water and shortly penetrated it.

Within 15 minutes after the checks were sprayed the beetles were noticeably affected. Within an hour the shrimps showed signs of DDT poisoning. Some of the beetle larvae were affected in a short

[1] Diesel Oil, Pacific specification number P.S. 200.
[2] Rohm and Haas, Lethane 384.
[3] Rohm and Haas, Triton B-1956, a fast breaking emulsifier spreader.

time. The culicine mosquito larvae in the checks were dead within a half hour. All of the shrimps, beetles and beetle larvae, and all other aquatic life were apparently dead within 20 hours.

SUMMARY AND CONCLUSIONS.—Extensive field tests were conducted in the spring of 1950 for the control of *Aëdes dorsalis* (Meigen) larvae, *Apus oryzaphagus* n. sp., *Apus biggsi* n. sp., and *Hydrous trianguaris* (Say) larvae using DDT as the toxicant. Three methods of applying the DDT were utilized in the tests.

1. The pre-treatment of the dry cultivated soil of the rice fields prior to flooding with a DDT-xylene type water emulsion (at the rate of 1 to 4 pounds of DDT per acre) and a DDT wettable powder suspension (at the rate of 4 pounds of DDT per acre) showed that, when the soil was sprayed within 9 days before flooding, (1) the flooded fields remained lethal to tadpole shrimps for a period of at least 2 weeks, (2) the *Aëdes dorsalis* larvae were effectively controlled as were the beetle larvae, (3) and the infestation of the fields by other mosquitoes did not occur for a period of approximately a month. The results obtained showed that this method is applicable where dry seed rice is broadcast with ground equipment before the fields are flooded.

2. Observations made after applying 50 per cent DDT wettable powder (at the rate of 1 to 4 pounds per acre) with the seed rice when plane-sown on a total of 3910 acres of commercial rice fields showed that (1) no shrimp infestation occurred even though many of these fields had heavy infestations in previous years, (2) no *Aëdes dorsalis* or other mosquito larvae appeared in the fields for a period of about a month, (3) the beetle larvae were effectively controlled in the individual fields observed.

In 1951 many of the commercial ric growers in California applied wettable powder DDT with their seed rice. No shrimp or beetle larvae damage occurred in approximately 60,000 acres treated by this method. In Butte County the spring rice field *Aëdes dorsalis* problem was greatly reduced in the treated areas.

The results obtained in 1950 and 1951 showed that this method is applicable where presoaked seed rice is plane-sown in the flooded fields and is an effective and economical method of control.

3. The spraying of flooded rice fields infested with mosquito larvae and shrimps with DDT-xylene type water emulsions (at the rate of 8 ounces to 1 pound of DDT per acre) was effective in killing the mosquito larvae, tadpole shrimps and beetle larvae within 20 hours. This method of control is also very effective on the adult beetles. The results obtained showed that this method of control is applicable where mosquito larvae, tadpole shrimps, beetles and beetle larvae appear in flooded, sown rice fields which have not been treated by either of the other two methods.

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Imported Cabbageworm Resistance to Insecticides[1]

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Since the introduction of chlorinated hydrocarbon insecticides many reports of insect resistance have appeared. In most cases, however, the resistance was developed under repeated exposure in the laboratory and relatively few species have shown tolerances to these insecticdes under natural conditions. Resistance to DDT in the field has been reported in this country and abroad for the housefly and several species of mosquitoes (Babers 1949; Barber & Schmitt 1948; King 1950; Bohart & Murray 1950). Such resistance has also been reported for the stable fly (Babers & Pratt 1951), the filter fly (Bruce 1950), bed bugs (Johnson & Hill 1948), a bark beetle and a scale insect (Babers & Pratt 1951), but as yet widespread resistance among these species has not been indicated. Recently Hulbert *et al.* 1952, have reported resistance to DDT in the body louse in Korea.

During the summer of 1951 a number of cabbage growers in the Kenosha-Racine area of Wisconsin experienced difficulty in controlling the imported cabbageworm, *Pieris rapae* (L.) with DDT. This material had given excellent control of cabbageworms during the previous four or five seasons. The second generation was nearing completion at this time (late July) and inspection of growers' fields showed, in many cases, two or three late instar larvae per plant in fields where up to four spray applications of DDT had been used in the preceding four or five weeks.

A number of possibilities might explain such a phenomenon: prevalence of wet weather may have reduced insecticide residues and prevented proper timing of sprays by the growers; grower carelessness such as failure to include a spreader-sticker may have given poor coverage; rapid plant growth at this time perhaps added to the percentage of unprotected foliage; there may have been incompatibility of solvents or toxicants of the DDT-TEPP mixture used for worm and aphid control; or the marketing of a poor quality DDT may have contributed to the poor control. In view of the development of insect resistance to certain chlorinated hydrocarbons, this possibility was also considered, although, to the authors' knowledge, no instance of such resistance among the Lepidoptera had been reported.

Experiments and Results.—In preliminary experiments, DDT wettable powder and emulsion were used, in combination with TEPP and alone. DDT concentrations of 0.5, 1, and 2 lbs. actual toxicant per acre were included using recently-marketed DDT and some that had been held over from 1950. Applications were made with a low-volume sprayer[3] on six-row plots, 50 paces long, using four replications. A commerical spreader-sticker was used and good coverage obtained. Results clearly indicated that DDT did not give efficient control in any of the forms or combinations used, even at the two pound dosage.

Inspection of the area revealed that DDT from at least three companies had been used with comparable poor results and sample analysis by the manufacturer showed proper quality and formulation of the product. The DDT being used was found to be giving good control of potato leafhoppers and several other insect species in the area, hence inferior insecticide was not being used.

A large number of larvae were collected from a previously DDT-sprayed field and equal numbers placed on cabbage plants and sprayed in the laboratory. DDT wettable powder was used in making up sprays in which a geometric progression of concentrations from 1:200 to 1:6400 actual toxicant were tested. Two replications were included and spraying was done with an air compresor-type sprayer using a Devilbiss atomizer at 25 pounds pressure. Thirty-five milliliters of spray were applied per plant, this amount being the maximum possible without run-off. The results are given in table 1 which shows that DDT was not effective in causing a high mortality of the imported cabbageworm from the insect population tested, and that after 50 per cent mortailty was reached, only slight enhancement of kill

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

[2] The authors wish to gratefully acknowledge the generous technical assistance given them by J. E. Casida, C. C. Doane, and J. P. Eastwood.

[3] Kupfer.

was obtained by increased dosages, even though concentrations were increased by sixteen times.

Table 1.—Cabbageworm control in the laboratory 46 hours after application of various concentrations of DDT. Kenosha, Wisconsin. 1951.

CONCENTRATION OF DDT	LIVING LARVAE PER PLANT
1:200	3.5
1:400	4.0
1:800	5.5
1:1600	4.5
1:3200	5.0
1:6400	10.0
Check	9.0

With this indication that cabbageworms in the Kenosha county area were tolerant to DDT a check of certain other areas in the state was made to determine the extent to which DDT-resistance was prevalent. In doing this identical control procedures were carried out at a number of points where sufficient cabbageworms could be found. Plots were treated north of Milwaukee (40 miles north of Kenosha), at Green Bay (125 miles north of Kenosha), and at Peshtigo (170 miles north of Kenosha), as well as several in the Kenosha area. Insecticides used were DDT, TDE, parathion, and CS-708, preliminary experiments having indicated that the latter three materials would give satisfactory control of the resistant worms. In this set of experiments, plots containing about 100 cabbage plants were used, replicated four times for each treatment, and uniform applications were made with a knapsack sprayer.

A number of larvae were collected from each of the test areas and brought back to the laboratory where they were placed on cabbage plants and sprayed with DDT at three concentrations. Six replicates of five larvae per plant were used in each case, except where the supply of larvae would not permit.

Table 3.—Control of cabbage worms from various localities 24 hours after treatment in the laboratory with indicated concentration of DDT. Kenosha, Wisconsin. 1951.

CONCENTRATION OF DDT	LIVING LARVAE PER PLANT			
	Larvae Collected from			
	Milwaukee	Green Bay	Peshtigo	Kenosha
1:200	0.0	0.6	0.0	1.3
1:800	0.0	0.6	0.6	3.3
1:3200	0.3	—	—	3.6
Check	3.0	—	3.0	4.3

The results of the above tests, tabulated in tables 2 and 3, show that the resistance of the cabbageworm to DDT is not widespread since comparable treatments gave widely different control on larvae from the Kenosha area as contrated to those from other regions Excellent, almost identical control was obtained with parathion, CS-708, DDT or TDE in locations other than the Kenosha area while in this region, the lower concentration of DDT was highly significantly less effective as a control material, and at the 2 pound level was significantly less effective than either CS-708 or parathion. TDE was also found to be somewhat less effective than CS-708 or parathion in the Kenosha area. Table 2 shows that control with TDE at 8 ounces per acre was only about as good as that of DDT at the 2 pound level, in some cases being significantly less effective than parathion or CS-708.

Table 2.—Cabbageworm control 48 hours after indicated treatments at Milwaukee, Green Bay, Peshtigo, (*1*, *2* and *3*) and Kenosha, Wisconsin. 1951.

TREATMENT		LIVING LARVAE PER 10 PLANTS				LIVING LARVAE PER 10 PLANTS			
		Location of Tests							
Material	Rate of Actual Toxicant/ Acre (lbs.)	—1—	—2—	—3—	MEAN CONTROL[1] (PER CENT)	Tests in Kenosha Area			MEAN CONTROL[2] (PER CENT)
DDT	0.5	12	2	1	91	83	67	44	46
DDT	2	5	0	0	98	36	35	20	72
CS-708	0.5	10	2	0	94	10	15	9	90
Parathion	0.25	22	2	1	90	12	15	10	89
TDE	0.5	14	3	0	92	30	23	19	79
Check		150	22	15	0	168	187	57	0
L.S.D. 5 per cent		6.5				25.7	11.5	8.3	
L.S.D. 1 per cent		9.2				36.0	16.2	11.5	

[1] Mean per cent control in areas other than Kenosha-Racine counties.
[2] Mean per cent control in Kenosha county area.

Table 4.—Cabbageworm control 48 hours after indicated treatments. Kenosha area, Wisconsin 1951.

Treatment, Material per Acre	Living Larvae per 10 Damaged Heads						Mean Per Cent Control[2]
	Test No.[1]						
	1	2	3	4	5	6	
DDT 8 oz.	15	4	6	16	7	0.5	70
DDT 32 oz.	11	2	2	5	6	0.5	84
Dilan 8 oz.	3	1	1	2	1	0.2	95
Check	49	19	22	34	26	7.2	0
L.S.D. 5 per cent	9.3		11.1		2.8		
L.S.D. 1 per cent	13.3		15.9		4.0		

[1] Tests at various locations within a five-mile radius of the area where resistant insects were first found.
[2] Test number 6 omitted as number of larvae was very small.

The above results having shown that DDT-resistant cabbageworms were not widespread, a number of plots were treated within about a five-mile radius of where resistance was known to occur in an attempt to determine the distribution of these insects. DDT at two concentrations and Dilan were used as insecticides at six locations within this area. Plots contained about 100 plants and treatments were replicated four times in a randomized block design. The results, which are given in Table 4, show that DT-resistant insects were present in all locations with the possible exception of test No. 6. The location of test No. 6 was the farthest removed from the area where resistant worms were first observed and may have been on the periphery of the resistant-insect area. It was extremely difficult to locate fields outside a 6–8 mile radius of the area in which resistance was first found where three were sufficient larvae to obtain control data. Since the farmers in these sections used DDT, it would appear that satisfactory control was being obtained and that the worms if resistant were not strongly so.

Table 5.—Cabbageworm control with various insecticides during 1951 as compared with that of the 1947–50 period. Tests in the Kenosha area Wisconsin.

Treatment Material and Ounces per Acre	Control of Cabbageworm Larvae	
	1951 (per cent)	1947–50 (per cent)
DDT—16	59	95
Q-137[1]—16	29	88
TDE—16	79	93
Methoxychlor—16	47	61
Parathion—4	84	91
Metacide—4	85	—
Malathon—16	83	53 (4 oz.)
269[2]—4	85	—
Chlordane—16	23	16
Toxaphene—16	54	26
Lindane—4	60	61 (1 lb. BHC) 12% gamma)
Lead arsenate—64	52	—
CPR[3] dust (25%)	75	—
Rotenone dust (0.75%)	—	61
Pyrethrum dust (0.15% pyrethrins)	—	82

[1] 1,1-dichloro-2, 2-bis(*p*-ethyl phenyl)ethane. Rohm and Haas Company.
[2] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa-hydro-1,4,5,8-endo-endo-dimethanonaphthalene. Julius Hyman and Company.
[3] Contains piperonyl cyclonene 2.5% pyrethrins 0.25%, rotenone 1.25%. U. S. Industrial Chemicals Company.

The above results having shown that DDT-resistant cabbageworms were not widespread, a number of plots were treated within about a five-mile radius of where resistance was known to occur in an attempt to determine the distribution of these insects. DDT at two concentrations and Dilan were used as insecticides at six locations within this area. Plots contained about 100 plants and treatments were replicated four times in a randomized block design. The results, which are given in Table 4, show that DT-resistant insects were present in all locations with the possible exception of test No. 6. The location of test No. 6 was the farthest removed from the area where resistant worms were first observed and may have been on the periphery of the resistant-insect area. It was extremely difficult to locate fields outside a 6–8 mile radius of the area in which resistance was first found where three were sufficient larvae to obtain control data. Since the farmers in these sections used DDT, it would appear that satisfactory control was being obtained and that the worms if resistant were not strongly so.

Experiments were carried out in the Kenosha area in which a number of insecticides were used to determine their effectiveness in controlling DDT-resistant cabbageworms. Table 5 contains the information obtained in such tests together with a comparison of results obtained with similar treatments in the Kenosha area in previous years.

These results served to point out that resistance in the imported cabbageworm was shown to Q-137 as well as to methoxychlor and TDE although the level of tolerance acquire toward the latter two materials was less pronounced. The overall control with parathion was also somewhat less than that of previous years although this material and the closely related compounds, metacide and malathon, were reasonably effective. Results with parathion were inconsistent within the Kenosha area, the value of 84 per cent reported in table 5 being derived from control plots in which larval mortality varied from 55 to 98 per cent. A comparison of the control obtained with

Table 6.—Control of resistant (R) and susceptible (S) cabbage worms in the laboratory at various times after treatment. Kenosha, Wisconsin. 1951.

Treatment, Material and Rate	Mean Per Cent Larval Mortality in Hours					
	4		8		16	
	R	S	R	S	R	S
DDT, 1:2000	20	46	20	58	30	89
Piperony butoxide, 1:100	15	11	23	36	35	46
DDT, 1:2000+ Piperonyl butoxide, 1:100	10	22	40	39	42	65
Check. Solvent only.	6	4	6	6	6	12
L.S.D. at 5 per cent level	9.9		11.5		14	
L.S.D. at 1 per cent level	13.4		15.5		18.5	

CPR dust in 1951 with rotenone and pyrethrum dusts in previous years indicates that no resistance has developed to these materials. CS-708 proved to be highly effective in 1951 as it had in other years. Of the other materials tested, 269 was the only material which gave good control of resistant cabbageworms.

For a number of years it has been known that certain materials had a synergistic activity with some insecticides. Perry & Hoskins (1950) reported that they were able to enhance the kill obtained with DDT on a resistant strain of houseflies by the addition of piperonyl cyclonene.

A laboratory test was conducted to check the effect of piperonyl butoxide when added to DDT on the mortality of DDT-resistant cabbageworms. Larvae were collected from an area of known resistance and from an area where resistance was not present. Discs of a suitable size were removed from inner cabbage leaves and placed in the bottom of petri dishes where they received a constant amount of insecticide spray. Technical DDT, dissolved in xylene, was sprayed on the leaf discs and the solvent allowed to evaporate before larvae were put in the Petri dishes, 6–8 per dish, with twelve replications. About one milliliter of water was added to each petri dish before the lids were put on so that the leaf discs would remain relatively turgid. Mortality counts were taken at 4, 8, and 16 hours after treatment and are summarized in table 6.

This test indicated that no synergistic action need be present to explain the results obtained. In each count, the control observed with the susceptible worms was highly significantly different from that of resistant larvae where DDT alone was used. This differeence is not so great where piperonyl butoxide was included, but the larvae would not feed normally when this compound was used and no clear cut effect of the added material was shown.

Discussion.—Very early in the work on insect resistance to DDT, Wiesmann in 1947 (Babers 1949) found that increased dosage gave only slight enhancement of kill unless this increase was extremely drastic. Many workers have since found this to be the case and the results of the present experiments on resistant cabbageworms bear out this generality (tables 1, 2, 3, 4). One might infer from the data presented here that the populations of cabbageworms in which resistance was found were not homogeneously resistant but rather contained a percentage of larvae normally susceptiable to DDT as well as others of intermediate susceptibility. In table 5, it will be seen that when all tests conducted in the field are included, the mean control obtained with DDT at 8 ounces actual toxicant per acre was 59 per cent, while in a laboratory test (Table 6) a concentration of DDT which gave 89 per cent mortality of susceptible larvae gave only 30 per cent mortaility of those collected in a resistant area. The larvae used in the laboratory test reported in table 6 were collected from a field where a rigid DDT-control program had been practiced and where DDT susceptible specimens should have been killed. Although field and laboratory tests are not directly comparable, the low mortality obtained in this experiment with the resistant larvae would tend to support the above inference. These, however, were third generation larvae and it is therefore possible that the results obtained represent an increased resistance from one generation to the next.

In the area in which resistance in cabbage worms appeared, the only "newer insecticide" used for their control on a widespread basis and over a number of years has been DDT. This insecticide has been used in the Kenosha area since 1946 so that it is possible that about 15 generations of the imported cabbageworm have been exposed to this material. In work with other insects, *e.g.*, houseflies, it has been found that a marked resistance to DDT can develop in this number of generations (Lindquist & Wilson, 1948).

Specificity of resistance has received a considerable amount of study and workers in the field are by no means unanimous in the acceptance of any one view. From the biochemical aspect and our present knowledge of detoxification mechanisms, it would seem most likely that resistance would be restricted to that compound for which tolerance had been acquired plus other materials whose lethal action is due to them having identical, or near identical, physiological effect on some system through identical mechanisms. The literature to date would indicate that this is not always the case. In the experiments herein reported, resistance was found to be present for DDT and Q-137, as well as to TDE and methoxychlor although it was not so strongly evident in the case of the latter two compounds. These compounds are quite closely related chemically and although the order of resistance was not what one might expect from an examination their structural formulae, resistance to this group has been found in many cases where insect resistance has developed through exposure to DDT. Observations on control obtained with parathion would place this material in a doubtful category in so far as cabbageworm tolerance is concerned. In many fields excellent control was obtained with parathion while in one of the experimental plots and in at least two commercial applications, control with this material was only about 50 per cent. A trend toward inconsistent results was present with the chlorinated hydrocarbons as well when field comparisons are attempted. CS-708 gave excellent control in all instances, indicating that faulty procedure would not account for these variations. It would appear that the development of resistance was extremely local and not equally developed in all fields within the area where tolerant larvae were manifest.

Sternberg *et al.*, (1950), showed that DDT was degraded by resistant houseflies to nontoxic compounds and Perry & Hoskins (1950, 1951a, 1951b) and Fullmer & Hoskins (1951), have shown that the addition of piperonlyl cyclonene inhibits this detoxification. Other compounds have been reported as having synergistic action with DDT on resistant houseflies (Bruce & Decker 1951; Sumerford *et al.* 1951), so that piperonyl butoxide was tested in this capacity on resistant cabbage worms. The effect of this material in the petri dish tests as previously indicated, is hard to evaluate since the larvae would not feed normally on tissue on which it was sprayed, hence no clear cut effect of the added material was detectable from the data obtained (Table 6).

CS-708 appeared to be the best material of those tested for the control of resistant cabbageworms, However, the length of time this material may prove effective is highly speculative. Fullmer & Hoskins (1951) found that the respiration patterns of CS-708-treated, DDT-resistant and susceptible houseflies were quite similar as were also mortalities, two criteria which differed greatly when DDT was the toxicant used. Bruce & Cecker (1951), however, reported that houseflies have developed tolerance to Dilan in five generations.

The area in Racine and Kenosha counties where cabbageworm resistance has developed is quite small. This area corresponds very closely to that were DDT was first used in Wisconsin for the control of these insects and where it has been used most extensively and consistently during the past five seasons. It is therefore quite reasonable that DDT-resistant cabbageworms appeared where they did and were not widespread throughout the State.

SUMMARY.—The imported cabbageworm, *Pieris rape* (L.), was found to have acquired field resistance to DDT and three related chlorinated hydrocarbons in a limited area in southeastern Wisconsin. This is the first reported instance of such development by a member of the Lepidoptera.

This resistant population of cabbageworms was not widespread throughout Wisconsin but has developed in an area with about a 6 to 8 mile radius in Kenosha and Racine counties. This area corresponds to that where DDT was first used in the State for the control of cabbageworms and where it has been used most consistently in the past 5 years during which time a total of 15 generations of larvae may have been subjected to DDT applications.

Of several insecticides tested, resistance to DDT and Q-137 was very marked and some tolerance was shown for TDE and methoxychlor. Control with parathion

was somewhat erratic within the resistant area but in general parathion, metacide and malathon gave satisfactory results. CS-708 gave excellent control of both DDT-resistant and susceptible larvae and 269, in less extensive tests, was highly satisfactory from the control of resistant cabbageworms.

Piperonyl butoxide did not show synergistic action to DDT on resistant cabbageworms. However, complicating factors in the test gave inconclusive results.

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House Fly Response to Volatilized Chlorinated Hydrocarbon Insecticides[1]

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Certain commonly used chlorinated hydrocarbons give good residual control of house flies under laboratory procedures in which the insects are enclosed or confined to treated surfaces. However, when a treated surface is exposed to flies in an open test cage which permits the insects to select an untreated resting site, the control results may be relatively poor. Previous studies by the senior author demonstrated that panels treated with deposits of benzene hexachloride, chlordane, and DDD water suspensions were appreciably less toxic to flies than panels treated with water suspensions of DDT or methoxychlor. The residues from water suspensions were also observed to be appreciably more toxic to flies than kerosene solutions. Box-cages screened at one end were employed in these studies which permitted test flies to select untreated as well as treated surfaces for resting sites. Field experiments generally confirmed the results of the laboratory tests.

It was assumed from these studies that test procedures which enclosed insects or confined them to treated surfaces (*e.g.*, a petrie dish) did not differentiate between

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contact toxicity and fumigation from volatile insecticides, or account for the attractiveness or repellence of an insecticidal deposit. The relatively poor control obtained under field conditions with water suspensions of benzene hexachloride, chlordane and DDD, and kerosene solutions of DDT, methoxychlor and chlordane appeared to be due to a repellence of flies from the treated surfaces, while the fumigation effect of a volatile insecticide had relatively little control value in an open area such as a well ventilated dairy barn. A series of chlorinated hydrocarbon insecticides was, therefore, tested in an olfactometer as a means of determining the effect of volatilized residual insecticides on the common housefly.

PROCEDURE.—Eleven chlorinated hydrocarbons were tested: DDT and its analogs methoxychlor, DDD, and DFDT; chlordane; heptachlor, aldrin, and dieldrin; benzene hexachloride and lindane; and toxaphene. A proprietary water-suspendible concentrate (wettable powder) was tested as well as the technical grade of each toxicant. Two grades of kerosene (commercial grade kerosene and deodorized insecticide base) were also tested to determine the effect of a volatilized hydrocarbon solvent.

The olfactometer employed was essentially a Y-tube in which test flies were permitted to express a preference for odors carried into it by two parallel air ducts. This apparatus was a closed system in which a stream of air was divided and passed through a set of two 100 ml. jars, one of which was a clean empty jar while the other contained an insecticide to be tested. The parallel streams of air were conducted from the jars into the arms of a plastic Y-tube, 2 inches in diameter, to intermingle in the stem of the Y at a point where the test insects were introduced. Four sets of Y-tubes were in simultaneous operation. The air flow for each Y-tube averaged 50 liters per hour, with an average pressure of 2 pounds per square inch. The humidity was kept relatively constant by passing the air through a saturated NaCl solution, while the temperature of the air stream was held at 26° C. by means of a thermostratically controlled water bath. All tests were conducted in a dark chamber. Examinations of the Y-tubes were made under a red light after a test period of 90 minutes.

A proprietary water-suspendible concentrate (wettable power) was tested as well as the technical grade of the insecticide, since the residues from water suspensions were found in previous studies to be more effective than the residues from kerosene solution or water emulsion formulations. All of the insecticides were tested in the dry state. The quantity of insecticide placed in the test jars was proportional to the concentrations which were used in previous laboratory or field experiments. For example, 5 gms. of a 50 per cent DDT wettable powder was placed in the 100 m. test jar, since field data indicated effective controll of flies with a 2.5 per cent suspension spray. Five grams of the technical grade DDT was used, since a minimum of 5 per cent concentration in kerosene solution or water emulsion was required for adequate control. Not all of the concentrations indicated for other insecticides gave effective control in previous experiments. A 2.5 per cent DDD suspension or a 5 per cent methoxychlor kerosene solution, for example, gave poor residual control. These however were the maximum concentrations feasible as water suspensions or kerosene solution sprays.

In operation, the air flow was maintained through the apparatus for a period of 10 minutes before the test insects were introduced into the stem of the Y-tubes. Twenty-five female houseflies of a standard laboratory strain were anesthetized with carbon dioxide and introduced simultaneously into each of the Y-tubes. Upon recovering from the anesthetic, the flies moved freely within the Y-tubes, and tended to enter the arm of the tube from which the most attractive odors emanated. Where a fumigation effect did not exceed a 10 per cent kill, an average of only 23 per cent of the flies were inactive or remained in the stem of the Y-tubes after 90 minutes exposure. All tests were replicated four times.

Attraction or repulsion was determined by comparing the numbers of flies which came to rest in either the check arm (connected with the clean, empty jar) or the test arm (connected with the jar containing the insecticide tested). Where an equal number of flies remained in either arm of the Y, a neutral response was indicated. Attraction to the insecticide was indicated where an appreciably greater

number of flies entered the test arm (a plus difference, or positive response), while a greater number of flies in the check arm (a minus difference, or negative response) indicated repulsion to the volatilized insecticide. Responding flies were considered as only those which entered the arms of the Y-tube. Flies which were moribund or remained in the stem of the tube were considered inactive. The results for technical grade aldrin (Table 1) will serve as an example of how insect response was determined. Nine per cent of the flies were moribund, 12 per cent remained in the stem of the tube, while 79 per cent (an average of 19.75 flies) responded by entering and remaining in the arms of the Y-tube. Of these responding flies, 64.6 per cent (an average of 12.75 flies) entered the check arm, while 35.4 per cent (an average of 7.00 flies) entered the test arm. A differential of −29.2 per cent was indicated since the flies entering the check arm were considered as responding negatively to the volatilized insecticide.

All data were evaluated by the Chi-Square analysis for variance. Results were considered significant when deviations did not exceed a probability of 5 per cent, and highly significant when deviations did not exceed a probability of 1 per cent. Analysis of individual tests for homogeneity of results from replication to replication, allowing 3 degrees of freedom, indicated that all tests were significant except for technical grade dieldrin. A summary of all olfactometric tests are compiled in Table 1. Insecticides are listed in a series ranging from the most attractive (methoxychlor) to the most repellent (kerosene) in their relative effects on houseflies. The responses listed for dieldrin and for technical grade DDD were not significant. Results for the wettable powder of DDT and the technical grade of heptachlor were significant, while for all other insecticides the results were highly significant.

RESULTS.—Methoxychlor and DDT were significantly attractive to flies. The attraction of the wettable powder and technical grade of methoxychlor was highly significant. Results for dieldrin and technical grade DDD were not significant and the insecticides were considered relatively neutral in effect. All of the remaining insecticides were significantly repellent to flies. The repellence of toxaphene and heptachlor was moderate and equal in effect for both the wettable powder and technical grade. Chlordane and BHC were extremely repellent, but generally equal in effect for the two preparations of each toxicant. The degree of repellence for wettable powder or technical grade appeared to vary considerably for the remainder of the toxicants tested. Differences between these preparations, however, were significant for only aldrin and DDD where the wettable powders were the more repellent. The wettable powder of DDD was significantly more repellent than the technical grade, while for aldrin these differences were highly significant. Unrefined kerosene was extremely repellent and comparable with the wettable powders of lindane and aldrin. The insecticide base kerosene was only slightly less repellent.

No moribundity was observed for methoxychlor, DDT or kerosene. A high degree of moribundity due to fumigation effect occurred for heptachlor, lindane and BHC. The degree of volatilization apparently was comparable for the wettable powder and technical grade of heptachlor (58.3 and 45.0 per cent respectively). The wettable powders of lindane and BHC were the more effective with a moribundity of 87 per cent for lindane compared with 24.0 per cent for the technical grade, and 45 per cent for BHC compared with 26.0 per cent for the technical grade. Moribundity was relatively low for the remainder of the toxicants tested with a maximum of 9 per cent (aldrin technical grade).

DISCUSSION.—Results of these tests may indicate that diluents or other adjuncts have an appreciable influence on the effectiveness of insecticidal residues. The adverse effect of kerosene is apparent as a diluent for residual sprays, especially when applied to porous surfaces. Both grades of kerosene were extremely repellent to flies. Suspension concentrates of DDD and adrin (responses of −50.0 and −83.6 respectively) were significantly more repellent than the technical grade (responses of −9.8 and −29.2 respectively). Flies were exposed to equal quantities of the toxicant (as technical grade) for aldrin, while for DDD the amount of toxicant in the technical grade sample was twice that of the wettable powder. An explana-

tion for these results may be found in the adjuncts used in formulating the wettable powder concentrates. The diluents or spreaders used in these proprietary insecticides, however, were unavailable for examination.

There is some indication that the wettable powders were more volatile than the technical grade samples, as demonstrated by the degree of moribundity observed for the BHC and lindane tests. Fumigation effect (expressed in these tests by the moribundity observed) apparently has little correlation with the degree of repellence. Lindane and BHC were extremely repellent and the volatilized insecticides gave an appreciable fumigation effect. Chlordane and kerosene, however, were also extremely repellent, while little or no moribundity occurred following an exposure of flies for 90 minutes.

The concentrations of volatilized insecticide to which flies were exposed in these tests were appreciably greater than would be expected from residual deposits on wall surfaces. These tests, however, may serve as an index of relative attraction or repellence. Where an extreme degree of repellence to flies was indicated, an adverse effect on selection of resting sites may occur. An insecticidal deposit which will encourage flies to rest on a treated surface would appear to be more effective under field conditions. These studies may explain in part the superior control results obtained for residual deposits of water suspensions of DDT and methoxychlor as compared with water suspensions of BHC, chlordane and DDD or oil solutions of DDT and methoxychlor. Discrepancies in the evaluation of insecticides under laboratory conditions would be explained in part when results obtained by a free-choice, open testing device were compared with results obtained with a testing apparatus which enclosed and confined flies to insecticidal residues.

SUMMARY AND CONCLUSIONS.—Olfactometric tests indicated that methoxychlor and DDT were significantly attractive to flies when exposed to the volatilized insecticide. Dieldrin and the technical grade of DDD were neutral in effect. Heptachlor, toxaphene, DFDT, the wettable powder of DDD, aldrin, lindane, BHC and chlordane were all significantly repellent ranging from moderate repellence for heptachlor to extreme repellence for chlordane. Proprietary wettable powders of DDD and aldrin were significantly more repellent than the technical grade, indicating that these preparations were more volatile, or that adjuncts with a repellent effect may have been used in their formulation. Kerosene was extremely repellent and appears to be a poor solvent for fly sprays formulated for use as a residual insecticide. Considerable fumigation effect was observed for heptachlor, BHC and lindane. The wettable powders apparently were more volatile than the unprocessed technical grade. There appears to be no correlation between repellence and fumigation effect, since little or no moribundity occurred for the very repellent chlordane and kerosene samples or for the relatively attractive methoxychlor and DDT samples.

Effect of Load in Fumatorium on Sorption of Fumigants[1]

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Studies have already been made on the tolerance of citrus fruits and avocados to various fumigants tested against the oriental fruit fly, *Dacus dorsalis* Hendel (Lindgren & Sinclair 1951). During that investigation, the question arose as to the effect of the size and composition of the load on the concentration of the fumigant in the gas phase. A commodity that is being fumigated may sorb a fairly large amount of the gas, the degree of sorption depending on the character of the commodity and the quantity being fumigated, and on the fumigant used. If the commodity is packed in a material such as corrugated cardboard, excelsior, or shredded paper, additional amounts of fumigant are sorbed. Under such conditions, the packing material may sorb enough of the gas to reduce the concentration in the fumatorium below the amount essential to kill the insects. On the other hand, commodities fumigated in packing materials in which gas exchange does not easily occur may be injured by the release of the sorbed fumigant from the packing material during the storage period. Some fumigants that are readily sorbed by commodities during fumigation react subsequently with the tissues and are so changed in chemical constitution as to be no longer toxic to the insects.

The main object of the present investigation has been to determine the effect of the load on the concentration of the fumigant that remains in the gas phase in the fumatorium at different times during the fumigation period. Experimentally, the task is simply this: the fumigation chamber is filled with a load of the commodity that is being tested, the fumigant is evaporated and thoroughly mixed within the chamber, and known volumes of air are withdrawn at intervals for determining, by chemical methods, the concentration of the fumigant that remains in the gas phase. The difference between the quantity of fumigant initially placed in the fumatorium and that determined in the gas phase is the amount sorbed by the exposed surfaces of the chamber and its load. The rate of sorption by the load can be graphically shown by plotting the milligrams of the fumigant per liter of air in the fumatorium against the time of exposure.

MATERIALS AND METHODS.—The fruit samples used in these experiments consisted of Valencia and navel oranges of orchard-run quality in field boxes of approximately 2-cubic-foot capacity. The fumigation experiments were performed in 100-cubic-foot, airtight fumatoria. Be-

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Table 1.—Physical constants of fumigants used in these experiments.[1]

FUMIGANT	FORMULA	MOLECULAR WEIGHT	COLOR AND FORM	SPECIFIC GRAVITY (Grams per Millilitgr)	BOILING POINT, °C.	SOLUBILITY (Grams per 100 Ml. Water)
1. Methyl bromide	CH_3Br	94.95	Col. liq. or gas	1.732 $\frac{0}{0}$	3.56	0.09
2. Ethylene dibromide	CH_2BrCH_2Br	187.88	Col. liq.	2.1701 $\frac{25}{4}$	131.6	0.431^{30}
3. Ethylene chlorobromide	CH_2ClCH_2Br	143.43	Col. liq.	1.689 $\frac{19}{4}$	107–108	0.688^{30}
4. Hydrocyanic acid	HCN	27.008	Col. liq. or gas	.699 $\frac{20}{4}$	26.0	∞[2]

[1] Data from *Handbook of Chemistry and Physics*, 31st edition, 1949, Chemical Rubber Publishing Co., Cleveland, Ohio.
[2] ∞ = soluble in all proportions.

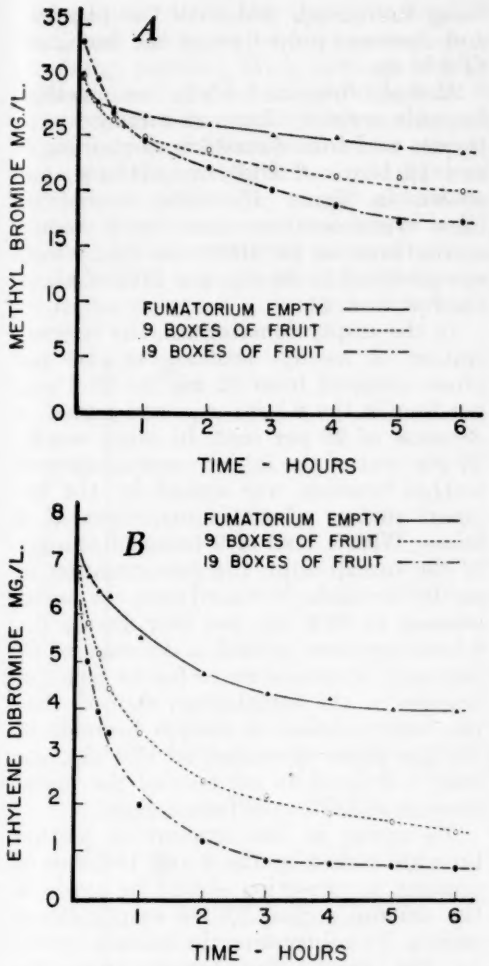

FIG. 1.—Relation between load (boxes of oranges) in a 100-cubic-foot fumatorium and concentration of fumigant in gas phase at various sampling intervals: (A) methyl bromide (dosage, 2 pounds per 1000 cubic feet; temperature, 70° F.); and (B) ethylene dibromide (dosage, 0.5 pound per 1000 cubic feet; temperature, 70° F.)

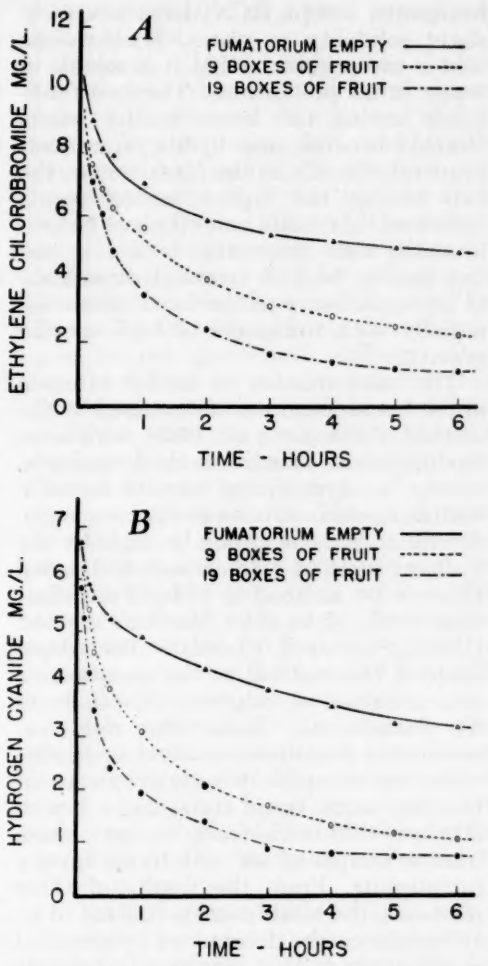

FIG. 2.—Relation between load (boxes of oranges) in 100-cubic-foot fumatorium and concentration of fumigant in the gas phase at various sampling intervals: (A) ethylene chlorobromide (dosage, 0.75 pound per 1000 cubic feet; temperature, 70° F); and (B) hydrogen cyanide (dosage, 0.5 pound per 1000 cubic feet; temperature, 70° F.)

fore fumigation, the fruit samples were placed in a temperature-controlled chamber and brought to a temperature of 70° F., at 80 per cent relative humidity. All fumigations were conducted at a temperature of 70° F., with continuous circulation of air within the fumatorium. The loads in the two fumatoriums consisted of 9 and 19 wooden field boxes of oranges, respectively, each box weighing approximately 60 pounds. The space occupied by the 9 boxes was 18 cubic feet, and by the 19 boxes, 38 cubic feet. Since the samples were composed of orchard-run fruit of various sizes, the interspace between the oranges was not determined.

In experiments designed to determine the effect of a typical packing material on the sorption of the gas during fumigation, excelsior was used in avocado shipping flats, in amounts equivalent to that used for the commercial shipment of avocados. In these experiments 50 shipping flats occupying a space of 32 cubic feet in the fumatorium were used in each fumigation.

The fumigants used were methyl bromide, ethylene dibromide, ethylene chlorobromide, and hydrocyanic acid. Some of the physical constants of these four fumigants are listed in table 1. All the

fumigants, except HCN, have relatively slight solubility in water. Hydrocyanic acid is exceptional in that it is soluble in water in all proportions. The two fumigants having the lower boiling points (methyl bromide and hydrocyanic acid) evaporated easily in the fumatorium; the two having the higher boiling points (ethylene dibromide and ethylene chlorobromide) were evaporated by air circulation and by heat. A thorough circulation of air is necessary in the fumatorium, especially with fumigants of high specific gravity.

The concentration of methyl bromide in the fumatorium was determined by the method of Stenger *et al.* (1939), with some modifications. Their method consists, chiefly, in hydrolyzing methyl bromide with monoethanolamine and subsequently determining the resulting bromide by the Volhard method (Hillebrand & Lundell 1929) or by Kolthoff & Yutzy's modification (1937) of Van der Meulen's method (1931). Sinclair & Crandall (1952) have adapted this method to the quantitative determination of ethylene dibromide in the fumatorium. Under the right experimental conditions, monoethanolamine will react completely with ethylene dibromide in the liquid state, and will sorb ethylene dibromide from the gas phase from a sample of air withdrawn from a fumatorium. From the results of these reactions, the total bromide content of an air sample can be determined by chemical analysis, and the ethylene dibromide equivalent can be calculated. A similar method has been successfully developed by Sinclair & Crandall for the quantitative determination of ethylene chlorobromide.

A modified Liebig silver-nitrate volumetric method was employed for the determination of hydrocyanic acid, the endpoint of the titration being determined by the use of a turbidimeter.

EFFECT OF LOAD ON THE TIME-CONCENTRATION CURVES OF VARIOUS FUMIGANTS.—The data in figures 1 and 2 show the influence of the load in the fumatorium on the decrease in concentration of the fumigant in the gas phase. Time-concentration curves are given for the four different fumigants. It can be seen that the amount of fumigant sorbed by a commodity during fumigation is correlated with the character of material being fumigated, and with the physical and chemical properties of the fumigant (Table 1).

Methyl Bromide.—Data on methyl bromide recovery from an empty fumatorium and from fumatoria containing 9 and 19 boxes of fruit, respectively, are shown in figure 1A. The dosage in these experiments amounted to 2 pounds methyl bromide per 1000 cubic feet, which is equivalent to 32 mg. per liter of air in the fumatorium.

In the empty fumatorium, the concentration of methyl bromide in the gas phase dropped from 32 mg. to 23.7 mg. per liter in the 6-hour exposure period, a decrease of 26 per cent. In other words, 26 per cent of the initial concentration of methyl bromide was sorbed by the exposed surface of the fumatorium in 6 hours. With a load of 9 boxes of oranges in the fumatorium, the concentration of methyl bromide decreased from the initial amount to 20.2 mg. per liter during the 6-hour exposure period, a decrease of 37 per cent. A similar curve for 19 boxes of oranges in the fumatorium showed that the concentration of methyl bromide in the gas phase decreased to 17.3 mg. per liter, a drop of 46 per cent of the initial amount added to the fumatorium.

To arrive at the amount of methyl bromide sorbed by the 9 and 19 boxes of oranges, a correction should be made of the amount sorbed by the empty fumatorium. By subtracting the amount sorbed by the empty fumatorium from the amount sorbed by the two different loads, the amount of methyl bromide sorbed by the 9 and 19 boxes of oranges (11 and 20 per cent of the initial dosage, respectively) will be obtained.

Ethylene Dibromide.—Similar curves for ethylene dibromide at a dosage of 0.5 pound per 1000 cubic feet are shown in figure 1B. This dosage, after correction for impurity in the fumigant, is equivalent to 7.68 mg. per liter of air in the fumatorium.

In the empty fumatorium, 48.5 per cent of the initial concentration of ethylene dibromide was sorbed by the exposed surface in 6 hours. The curve for the empty fumatorium shows graphically that the concentration of ethylene dibromide fell from 7.68 to 3.96 mg. per liter during the time of exposure. With a load of 9 boxes of oranges, the concentration of ethylene

dibromide decreased approximately 82 per cent during the 6-hour period, or to 1.38 mg. per liter. With 19 boxes of fruit, the amount of the fumigant decreased 92 per cent in 6 hours. In other words, only 0.61 mg. per liter remained in the gas phase at the end of the fumigation period. Ethylene dibromide, at 0.5 pound per 1000 cubic feet, was therefore highly sorbed by the 9 and 19 boxes of oranges when it is considered that these two samples occupied only 18 and 38 cubic feet, respectively, of a total capacity of 100 cubic feet.

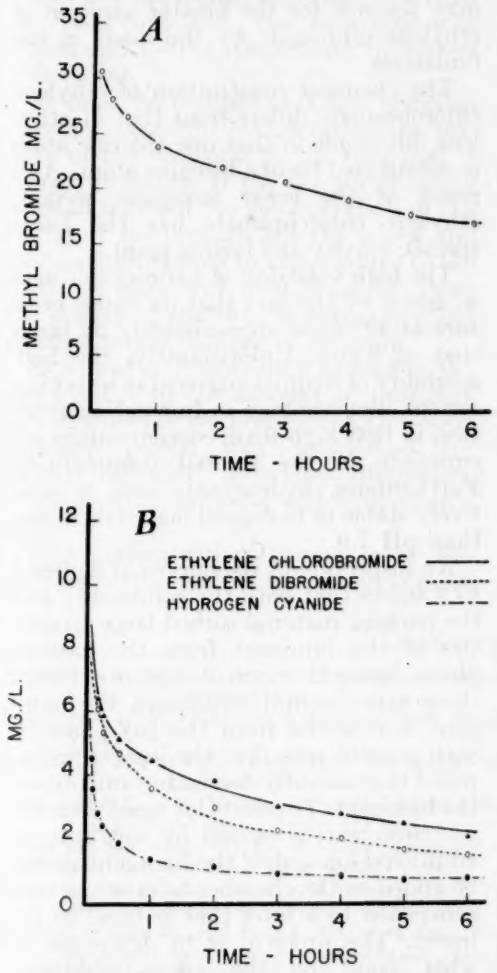

FIG. 3.—Relation between load (avocado shipping flats of excelsior) in a 100-cubic-foot fumatorium and concentration of fumigant in gas phase at various sampling intervals: (A) methyl bromide (dosage, 2 pounds per 1000 cubic feet; temperature, 70° F.); and (B) ethylene chlorobromide (dosage, 0.75 pound per 1000 cubic feet), ethylene dibromide (dosage, 0.75 pound per 1000 cubic feet), and hydrogen cyanide (dosage, 0.5 pound per 1000 cubic feet), all at a temperature of 70° F.

Ethylene Chlorobromide.—The curves for ethylene chlorobromide were drawn from data obtained at a dosage of 0.75 pound per 1000 cubic feet, which, after correction for impurity in the fumigant, is equivalent to 11.63 mg. per liter of air in the fumatorium (Fig. 2A). The dosages used in these particular experiments are higher than those used for ethylene dibromide, but the slope and shape of the curves for these two closely related halogens are not significantly different. During the 6-hour period, the concentration in the empty fumatorium dropped from 11.63 to 4.88 mg. per liter, which is equivalent to a decrease of 58 per cent. With loads of 9 and 19 boxes of oranges, the concentration in the chamber dropped to 2.22 and 1.10 mg. per liter, a decrease of approximately 81 and 91 per cent, respectively. The difference between the amount sorbed by the empty fumatorium and that sorbed by the load gives the amount sorbed by the 9 and 19 boxes (23 and 32.5 per cent, respectively).

Hydrocyanic Acid.—The time-concentration curves for hydrogen cyanide are given in figure 2B. The dosage used in these experiments was 0.5 pound per 1000 cubic feet, which, after correction for the impurity in the fumigant, amounted to 7.38 mg. per liter.

That hydrogen cyanide is highly sorbed on surfaces is clearly demonstrated by noting the course of the curve for the empty fumatorium. The concentration in the gas phase decreased from 7.38 to 3.16 mg. per liter during the 6-hour period. In other words, 57 per cent of the hydrogen cyanide was sorbed by the walls of the fumatorium. The high sorptive capacity of this fumigant is probably positively correlated with its solubility in water in all proportions. Moisture films on surfaces and biological materials generally increase the sorptive capacity of hydrogen cyanide from the gas phase during a fumigation. With loads of 9 and 19 boxes of fruit, the concentration fell to 1.03 and 0.70 mg. per liter, a decrease of 86 and 91 per cent of the initial concentration, respectively. Although liquid hydrocyanic acid has a low boiling point (26° C.) and an exceedingly high vapor pressure at ordinary laboratory temperatures (654.4 mm. at 22° C.) the load of

19 boxes of oranges and the walls of the fumatorium sorbed nearly all the fumigant from the gas phase.

SORPTION OF VARIOUS FUMIGANTS BY EXCELSIOR PACKING MATERIAL.—It was found early in our experiments on commodity treatments that the material in which a product was packed for shipment sorbed large quantities of the fumigant. Of the many kinds of packing materials available, excelsior in avocado shipping flats was chosen for these experiments. the sorption of the different fumigants by this material is shown in figure 3.

The concentration of methyl bromide used in this experiment (32 mg. per liter) was the same as that used in the fruit experiment. With a load of 50 flats of excelsior, occupying 32 cubic feet in the fumatorium, the concentration of methyl bromide decreased from 32 to 17.1 mg. per liter, or approximately 46 per cent (Fig. 3A). This value includes the methyl bromide sorbed by both the exposed surface of the fumatorium (26 per cent) and the excelsior packing material (20 per cent).

Similar curves were constructed and reported for ethylene chlorobromide, ethylene dibromide, and hydrogen cyanide (Fig. 3B). In comparing these curves, it should be noted that the concentration of hydrocyanic acid used in these experiments was different from that of the other two fumigants. The data for the curves for both ethylene chlorobromide and ethylene dibromide were determined on the same concentration of fumigant. The excelsior material sorbed these two fumigants at about the same rate during the 6-hour exposure. During the fumigation period, the concentration of ethylene chlorobromide dropped from 11.63 to 2.02 mg. per liter, a decrease of approximately 83 per cent; the concentration of ethylene dibromide fell from 11.52 to 1.49 mg. per liter, a decrease of 87 per cent. The differences between these two series of values are not significant. With hydrocyanic acid, the curve descends very sharply, as shown by the fact that 81 per cent of the initial concentration was sorbed by the excelsior material after 1 hour of exposure. During the total exposure period, the concentration fell from 7.38 to 0.73 mg. per liter, a sorption of approximately 90 per cent.

COMMENTS.—It is interesting to observe the differences in the various curves in figures 1 to 3, and to note the differences in the physical properties of the various fumigants (Table 1). For example, the boiling point of methyl bromide is 3.56° C., whereas that of ethylene dibromide is 131.6° C. Methyl bromide thus has a much higher vapor pressure than ethylene dibromide. Ethylene dibromide, on the other hand, has a much higher specific gravity than methyl bromide, and higher solubility in water. These differences in physical properties may account for the greater sorption of ethylene dibromide by the loads in the fumatoria.

The chemical constitution of ethylene chlorobromide differs from that of ethylene dibromide in that one chlorine atom is substituted for one bromine atom. As a result of the lower molecular weight, ethylene chlorobromide has the lower specific gravity and boiling point.

The high volatility of hydrocyanic acid is shown by the fact that its vapor pressure at 22° C. is approximately 33 times that of water. Unfortunately, the high solubility of hydrocyanic acid in water is a serious disadvantage in fumigation practice, in that high toxic concentrations accumulate in the treated commodities. Furthermore, hydrocyanic acid is relatively stable in biological materials at less than pH 7.0.

An inspection of the curves in figures 1 to 3 shows that both the commodity and the packing material sorbed large quantities of the fumigant from the gaseous phase during the time of exposure. Under these experimental conditions, the fumigant is removed from the gas phase at such a rapid rate that the insects are exposed to constantly decreasing amounts of the fumigant. To offset this rapid decrease in concentration caused by sorption, an additional amount of the fumigant should be added to the chamber to raise the concentration to a level that is toxic to the insect. The problem is to determine at what point on the curve additional amounts of the fumigant may be added to the chamber without causing injury to the fruit.

The relation between dosage, time of exposure, and temperature is fundamental to successful fumigation practice. For example, if a given insecticide produces 100 per cent mortality of an insect at 2

pounds per 1000 cubic feet at 80° F., a lowering of the temperature 10 degrees is usually compensated for by increasing either the dosage 0.5 pound or the time of exposure 0.5 hour. This relationship was established by Latta (1940, 1941), and used extensively by Steinweden (1945). For methyl bromide, English (1944) has placed these variables into the following equation:

$$D\,E = 40.23e^{-0.030T},$$

where D = the dosage in pounds of CH_3Br per 1000 cubic feet, E = the exposure in hours, and T = the temperature in degrees Fahrenheit.

It must be realized that this equation does not take into consideration the toxicity of the fumigant to the fruit that is being fumigated. If the margin of safety is small between the concentration of the fumigant required to kill the insect and that sufficiently low to avoid injury to the fruit, an increment of increase in either the dosage or the time of exposure could produce severe damage to the fruit.

SUMMARY.—The relation of load in the fumatorium to the amount of fumigant sorbed from the gas phase during a 6-hour exposure period was determined for methyl bromide, ethylene dibromide, ethylene chlorobromide, and hydrocyanic acid.

Time-concentration curves were determined with the various fumigants in an empty fumatorium, and in fumatoria containing loads of 9 and 19 boxes of citrus fruits (Valencia and navel oranges) occupying 18 and 38 cubic feet, respectively. Similar curves were determined on 50 avocado shipping flats of excelsior, which occupied 32 cubic feet in the fumatorium. All experiments were performed in 100-cubic-foot capacity airtight metal fumatoria.

These results are of practical value in that they show the high sorptive capacity of oranges and excelsior for the various fumigants, even though the commodities never occupied more than 38 per cent of the space in the fumatorium.

The amount of a fumigant sorbed by a commodity during fumigation depends on the character of the material being fumigated and on the physical and chemical properties of the fumigant.

Under these experimental conditions, ethylene dibromide and ethylene chlorobromide were sorbed to about the same extent on the exposed surface of the excelsior. The solubility of hydrocyanic acid in water in all proportions is highly correlated with its high sorption by the fruit and excelsior.

The sorption experiments with excelsior indicate that when fruit is fumigated it should be treated without packing materials. Dosages recommended for fruit, only, should not be used in fumigating samples that are packed or wrapped.

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BOOK NOTICES

AN INTRODUCTION TO ACAROLOGY, by Edward W. Baker and G. W. Wharton. The Macmillan Company, New York, 1952. 8¼×5½ inches. xiv+565 pp. frontis. 377 figs. cloth bound. $10.00 net.

In view of the increasing awareness of the importance of mites and ticks, and because such a work has been badly needed for years, it is a pleasure to welcome this outstanding book to the texts which economic entomologists cannot do without. Both authors, Dr. Edward W. Baker, of the Bureau of Entomology and Plant Quarantine, and Dr. G. W. Wharton of Duke University, are well-known acarologists. There are eight chapters, the first being an introduction that includes the collecting, preparation structure, development and ecology of mites in general. The remaining seven chapters cover the following suborders of the Acarina, Onchyopalpida, Mesostigmata, Ixodides, Trombidiformes, and Sarcoptiformes. There are keys to the groups comprising the suborders and to the 228 families. Each family is discussed diagnostically and there are lists of the genera and their type species. In addition there are numerous accounts of the biology and of the economic importance of various species, references to the literature, and numerous drawings of the representatives of each family, the whole comprising an excellent, concise and extensive introduction to acarology, which opens up a fascinating field for the ecologist, zoologist, and taxonomist. Mites are everywhere, under stones, bark, debris, rotting wood, in soil, water, moss, etc. Others are associated with plants and insects. Many are parasitic on bats, snakes, lizards, various vertebrates and invertebrates. Many are economic and medically important pests, such as gall, rust, grain, mushroom, citrus, cheese, itch, and follicle mites, those carrying diseases, etc. Others are found in the respiratory passages of snakes and honey bees. With such a wealth of field material close at hand and with such a reliable and carefully written "Introduction to Acarology," there certainly should be an increase in the number of students of acarology during the coming years. "No dramatization in lectures, radio or television is permitted" by The Macmillan Company. —H.B.W.

THE APHID GENUS PERIPHYLLUS, A SYSTEMATIC, BIOLOGICAL, AND ECOLOGICAL STUDY, by E. O. Essig and Frieda Abernathy. University of California Press, Berkeley and Los Angeles, 1952. 8½×5½ inches. viii+166 pp. 43 figs. cloth bound. $3.00.

This book which is aptly described by its title is the result of six years of intensive study, particularly of three species in the genus, by our well-known and versatile Professor Essig, assisted ably by Frieda Abernathy who is responsible for the excellent scientific illustrations and the detailed field studies. In all there are eleven chapters. Ten of them are each devoted to a single species, these being the sycamore maple aphid, the American maple aphid, the Colorado maple aphid, the California maple aphid, the Formosa maple aphid, the Koelreuteria aphid, the Japanese maple aphid, the Norway maple aphid, the boxelder aphid and the European maple aphid. Species of the genus Periphyllus occur over a large area of the world. For each species considered there are descriptions of the forms, historical, taxonomic notes, distributional records, and host plants. In addition the life history is given when known. The development of certain species and their life histories are very complex and this is well illustrated by the authors in their account of the California maple aphid in which 17 different types or forms of individuals were studied and recognized. In order to catalogue the types of this amazing species, additional symbols were created for their separation. This work should stimulate further study on the part of students who have the patience, and the urge to make additional discoveries. The field is wide open and the species of this genus are wide spread geographically and frequently numerically abundant. An interesting and important pioneer contribution.—H.B.W.

FOREST ENTOMOLOGY, by Samuel Alexander Graham. Third Edition. McGraw-Hill Book Company, Inc., New York, Toronto, London, 1952. 9×6 inches. x+351 pp. frontis. 85 figs. $6.00.

The third edition of Professor Graham's familiar and standard "Forest Entomology" has just appeared as one of The American Forestry Series published by the McGraw-Hill Book Company, Inc. The first edition was printed in 1929, the second in 1939. The present edition has been thoroughly revised so as to include new control techniques and other changes that have been developed over the intervening years. The author, who is well-known and highly regarded in his field, develops the principles of forest entomology in nineteen comprehensive chapters covering a historical review, methods and techniques for insect surveys in forests, the reproduction potential of forest insects, the environmental resistance to insect increase, insect population levels, various control methods such as by chemicals, by food supply modification, by parasites, and by silvicultural practices. The insects under consideration are grouped in accordance with their feeding habits, as leaf eaters, sap suckers, meristematic insects, phloem insects, phloem-wood insects, and wood destroyers. An extensive bibliography and an adequate index complete the volume. The entire work is a philosophical and concise presentation of the principles of forest entomology from all angles by an author who is thoroughly conversant with the subject and its various ramifications. Although certain forest insects are mentioned to illustrate principles and control practices, the text is fully abreast of the latest insecticides and their methods of application. This is a highly satisfactory book for students and foresters.—H.B.W.

THE FALSE SPIDER MITES OF CALIFORNIA (*Acarina: Phytoptipalpidae*) by A. Earl Pritchard and Edward W. Baker. University of California Press, Berkeley and Los Angeles, 1951. 10×6¾ inches. iv+93 pp. 45 figs. paper covers. $1.00.

This systematic, monographic study of the false spider mites of the family Phytoptipalpidae is volume 9, number 1 of the excellent University of California Press Publications in Entomology. Although the present paper is a taxonomic revision it includes consideration of several important economic species and the family as a whole is very well represented n the California fauna. In addition to keys to the North American genera and California species, there are descriptions of 24 new species. Some of the economic species are cosmopolitan in distribution.—H.B.W.

SCIENTIFIC NOTES

Soil pH in Relation to Japanese Beetle Populations

R. D. Wessel[1] and J. B. Polivka, *Ohio Agricultural Experiment Station, Wooster*

The Japanese beetle, *Popillia japonica* Newm., was first discovered in Ohio in 1931. Since that time a few new points of infestation have been recorded each year until, at present, 110 are known. During the past 10 years a progressive dispersal through natural flight of the beetle has taken place in several areas. In eight of these, continuous infestations of economic importance prevail.

A study of the effect of various factors of the edaphic environment was undertaken to gain information that might help to explain why the beetle population increases in some areas while other areas, with infestation records of the same age, remain relatively inactive. This paper presents the results of a four year study concerning the influence of soil pH on Japanese beetle populations.

Investigations under Controlled pH Conditions.—In August of 1949 a controlled experiment was established at Springhill Cemetery in Wellsville, Ohio, using five acidity levels. The normal pH of the area was found to be pH 4.30 to pH 4.50. The soil pH was adjusted by application of the following treatments.

1. Intended pH 3.00. 696.9 pounds of flowers of sulphur was added per acre.
2. Intended pH 4.30. Untreated.
3. Intended pH 5.75. 1333 pounds of pulverized agricultural limestone was added per acre.
4. Intended pH 7.00. 3000 pounds of pulverized agricultural limestone was added per acre.
5. Intended pH 8.00. 16,000 pounds of pulverized agricultural limestone was added per acre.

A plot size of 475 square feet was used and the treatments were replicated 6 times. The experimental area was plowed to a depth of four inches, the treatments were applied, and a disc was used to work the materials into the soil. Grass seed was sown and the entire area was covered with straw for the winter.

During July and August of 1949 counts of eggs and first instar larvae were taken in these plots to determine the possible effect of soil acidity on the oviposition sites chosen by the adult females. Three one-third square foot samples to a depth of four inches were taken weekly from each plot for four weeks and examined for eggs and first instar larvae. In 1950 six samples were taken from each plot during the third week in July. The results obtained from sampling the plots both years are shown in table 1 and the comparative significance of these data is shown in table 2.[2]

Table 1.—The number of eggs and first instar larvae found in the pH plots at Wellsville, Ohio, during July and August of 1949 and July in 1950.

Treatments (Intended pH)	1949		1950	
	Actual pH	Eggs and 1st Instar Larvae Per Sq. Ft.	Actual pH	Eggs and 1st Instar Larvae Per Sq. Ft.
3.00	3.86	39.3	3.90	11.2
4.30	4.28	31.4	4.30	8.3
5.75	4.80	28.3	4.80	9.5
7.00	5.26	28.9	5.30	5.7
8.00	6.83	18.0	6.80	3.0

Table 2.—The comparative significance between treatments of eggs and first instar larval counts taken from the pH experiment at Wellsville, Ohio, during 1949 and 1950.

	Treatments							
	1		2		3		4	
	1949	1950	1949	1950	1949	1950	1949	1950
2	−	−						
3	−	−	−	−				
4	−	−	−	−	−	−		
5	+	−	+	−	+	−	+	−

\+ Significant difference. − No significant difference.

Since the treated plots had not reached the desired equilibrium at the time the samples were taken, the actual pH values are included in the above table. The pH samples were taken during the July-August periods of each year.

The 1949 data show that the number of eggs and first instar larvae in the highest pH plots was significantly smaller than the numbers found in any of the other treatments. While the data for 1950 indicated a similar trend in population for the various treatments, no significance was found between the populations of the lowest and highest pH plots.

Larval counts were taken in October of 1949, 1950, and 1951. Six similar samples were examined from each plot in order to observe the extent of larval survival throughout the various pH levels. These data are shown in table 3 and the comparative significance between treatments in table 4.

Actual pH values in the above table were obtained by averaging the hydrogen ion concentration of soil samples taken during August, September, and October of each year.

In 1949 surviving larvae were significantly fewer in treatments one and five. In 1950 and 1951, the greatest number of larvae were found in treatment one while the lowest number were taken in treatment five.

Following the initial treatments and throughout the 1949 adult flight season, the plots to which sulfur was applied were practically devoid of vegetation. Even though the greatest number of eggs were found in these plots it is possible that the lack of succulent food in adequate quantity was largely responsible for the low number of larvae found in the fall of that year. However, by the time the adult flight season of 1950 occurred, plants which were suited to the acid condition of these areas had become well enough established to provide adequate food and thus promote the survival of the larvae which hatched from the eggs deposited in these plots.

The fact that the least number of larvae were consistently found in the plots of highest pH would seem to indicate that either (1) actually fewer eggs are laid in soil as it approaches alkalinity or (2) that hydrogen ion concentrations of this magnitude have some detrimental effect upon larval survival.

These data seem to indicate that optimum oviposition is closely associated with high acid soil con-

[1] This paper is a portion of the dissertation material presented to The Ohio State University by the senior author in partial fulfillment of requirements for the degree Doctor of Philosophy.

[2] The authors wish to credit Dr. D. R. Whitney of the Statistics Laboratory at The Ohio State University for his help in the analysis of these data. He applied the test developed by Mann & Whitney (1947).

Table 3.—The number of larvae found in the pH plots at Wellsville, Ohio, during October 1949, 1950, and 1951.

Treatment (Intended pH)	1949		1950		1951	
	Actual pH	Mean Number of Larvae per Sq. Ft.	Actual pH	Mean Number of Larvae per Sq. Ft.	Actual pH	Mean Number of Larvae per Sq. Ft.
3.00	3.80	33.3	4.10	34.8	4.20	30.5
4.30	4.25	53.3	4.30	25.3	4.50	28.5
5.75	4.80	55.7	4.80	26.0	5.10	24.5
7.00	5.25	52.8	5.30	26.8	6.18	22.7
8.00	6.80	36.5	6.80	23.2	7.66	18.2

ditions. However, since some eggs were found at pH 6.83, it is possible that the upper threshold for egg deposition probably occurs within the alkaline range.

The optimum pH for larval survival appeared to range downward from the vicinity of pH 4.50 to the point at which very little vegetation survived. This point, within the acid range, at which plant growth is inhibited will probably describe the lower threshold for larval development and survival. An upper threshold was not indicated by these data. Since larvae were found at pH 7.66, the upper limit of development must lie at an even more alkaline pH.

Investigations Under Natural Conditions.—The investigation of the relationship between larval populations and soil pH under natural conditions demanded experimental areas with a great latitude of soil pH variability. Golf courses which present an extensive, complex, and wide variation in types and conditions of soil offer the best opportunities for studies of this nature.

The experimental procedure required the selection of a number of random points in a golf course for study. At each location a larval population count and several borings for pH determination were taken.

The location of these studies was the Oakwood Country Club, Cleveland Heights, in September 1948, the Marietta Country Club, Marietta, in May 1950, and the Belleview Golf Course, Steubenville, in May 1950. The data taken are shown in table 5.

These data were also analyzed by D. R. Whitney. It may be noted that the Oakwood data exhibit a significant association of high numbers of larvae with low soil pH. In the Belleview Golf Course, the data indicate a similar association although statistical significance is lacking. The optimum range of larval distribution indicated by the data from these two locations fell between pH 4.00 and 4.50. This coincides rather closely with the optimum range suggested by the data from the controlled experiment at Wellsville. The data from Marietta, however, showed no such association. It may be noted also that in the Marietta area the entire range of soil pH was higher.

Table 5.—The relation of larval population to soil pH under natural conditions.

pH Range	Mean Number of Larvae per Sq. Ft.		
	Oakwood	Marietta	Belleview
3.8–3.9	15.0		
4.0–4.1	128.0		13.2
4.2–4.3	85.9		14.5
4.4–4.5	52.9		40.8
4.6–4.7	7.5		4.5
4.8–4.9	8.4	10.8	18.0
5.0–5.1	3.0	6.0	.0
5.2–5.3	12.6	14.2	6.0
5.4–5.5	5.1	17.4	.0
5.6–5.7	9.0	11.1	11.0
5.8–5.9	.0	4.5	1.5
6.0–6.1	1.3	2.0	18.0
6.2–6.3		6.0	.0
6.4–6.5		1.3	.0
6.6–6.7		15.0	9.0
6.8–6.9		13.0	
df = 3	$X^2 = 16.28$ $X^2.01 = 11.34$	$X^2 = .45$ $X^2.05 = 7.81$	$X^2 = 4.16$ $X^2.05 = 7.81$

Summary.—Data collected from experiments dealing with controlled soil pH levels indicated that female beetles laid more eggs in soils of high acidity. Larval counts revealed that the optimum soil pH for larval survival ranged from approximately pH 4.50 downward. Since larvae were found at pH 7.66

Table 4.—The comparative significance between treatments of larval counts taken from the pH experiments at Wellsville, Ohio, during October 1949, 1950, and 1951.

	Treatments											
	1			2			3			4		
	1949	1950	1951	1949	1950	1951	1949	1950	1951	1949	1950	1951
2	+	+	−									
3	+	+	+	−	−	−						
4	+	+	+	−	−	−	−	−	−			
5	−	+	+	+	−	+	+	−	+	+	−	+

\+ Significant difference. − No significant difference.

the upper developmental threshold must lie at an even greater alkaline pH. Studies under natural conditions showed that the greatest numbers of larvae were associated with the range pH 4.00 to 4.50.

It is concluded that larvae of the Japanese beetle have a broad tolerance of soil pH. Nevertheless, it is deemed possible that rapid population increases may be favorably influenced by low soil pH conditions.

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The Attached Bait Pan Fly Trap

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For many years, fly traps have been employed as a means of appraising domestic fly populations and as a supplementary method of control. Currently, the latter function has been relegated to a position of minor importance because of the more successful approaches of sanitation and chemical treatments in attaining acceptable fly abatement. In the evaluation of fly populations, the chief purpose of traps is to measure the qualitative aspects of fly prevalence. In addition, traps also provide an excellent tool to collect specimens for virologic or bacteriologic examination (Melnick 1949). For these functions, the standard USDA metal trap (Bishopp 1937) has proved to be too unwieldy and expensive in conducting routine sampling operations. To remedy these shortcomings, a smaller version of the USDA trap was designed (Coffey 1948) (Figure 1a). Despite the increased efficiency of the smaller unit, it did not meet fully the requirements of a moderately-priced, easy-to-handle trap. The increased need for such a device on the Communicable Disease Center's Poliomyelitis Investigations, Fly Control Program subsequently led to the adoption of a modification of the attached-bait pan type of fly trap, originally employed by Drs. L. R. Penner and J. L. Melnick[1] to sample fly populations in Connecticut and to collect flies for virological tests. This article describes the modified trap and its field usage.

The attached-bait pan trap depicted in Figure 1b evolved from the improvised prototype used by Penner & Melnick. Essentially, the trap consists of three main parts, the cage, bait pan, and metal standard. The cage (6.125 inches diameter, 8.125 inches high), has a removable screened lid and a built-in cone and is constructed to fit snugly over the upper rim of the bait pan. The latter (5.31 inches diameter, 4.5 inches high) can be described as a metal cylinder provided at the middle with a one and a half inch rib of hardware cloth. One end of the cylinder is solid. Both the cage and the bait pan have a single stove bolt attached to one of the three vertical support strips.

The metal standard is constructed of 1.25 by 1.25 inch angle iron, 23.25 inches in length, fitted with a curved handle of strap iron. Two 5.25 inch sections of angle iron welded are to the standard, one at the top and the second at mid-point. The latter serves as a footrest for forcing the standard into the ground, while the top bar is a hand support. Two keyhole slots bored into the standard at appropriate locations receive the heads of the stove bolts fastened to the bait pan and cage.

FIG. 1.—(a) Modified USDA trap left, (b) attached-bait pan trap right.

For trap operation, a quarter or half pint ice cream carton containing suitable fly attrahents is placed in the bait pan. The latter is then inserted into the open bottom of the cage after which the two sections are attached as a unit to the metal standard. The device can now be either inserted in the ground or suspended from a tree limb or fence.

Functionally, the trap operates the same as the conventional types. Flies are attracted to the bait, then move upwards towards the light source and through the cone opening into the cage. To determine if the qualitative sample of the fly population obtained by the attached-bait pan trap was similar to that yielded by the modified USDA type, limited comparative tests were effected at Troy, New York, Charleston, West Virginia, Muskegon, Michigan, Topeka, Kansas, and Phoenix, Arizona, in 1949. In each test, both types of traps were baited with the same ingredients (fish or meat, rotted fruits and vegetables) and operated for two periods of 24 hours each at two different sites in the same general area (usually a single block). The two trapping stations in most instances were at opposite ends of the same block. After operation of the two traps at opposite sites for one 24 hour sample, their positions were reversed for the second trap day. By not running the traps in juxtaposition, the influence of one trap on the capturing power of the other was minimized.

Results indicated that the composition of the flies captured by the attached-bait pan trap was similar to that shown in collections from the modified type. On a percentage basis, 94 per cent and 89 per cent of the flies collected by the modified and bait pan trap, respectively, consisted of *Musca domestica*, *Phaenicia sericata*, *P. pallescens*, *Phormia regina*, *Callitroga macellaria* and Sarcophagidae. Except for a reversal of rank order between the two species of *Phaenicia*, the sequence of prevalence was the same for both traps. A similar pattern was reflected in the individual data from each of the five cities. As would be anticipated, the volume of flies recovered by the modified trap usually exceeded that secured by the at-

[1] University of Connecticut and Yale University School of Medicine, respectively. The writer is indebted to these workers for providing him with a sample of their prototype trap and for suggestions regarding its improvements.

tached-bait pan trap, a result ascribed to the greater quantity of bait exposed with the larger trap. This discrepancy in volumes generally increased when fly populations were at maximum levels. In no test did the smaller trap fail to capture flies even when the number of specimens taken by the modified trap was of a low order of magnitude.

From these tests and from substantiating evidence supplied by two seasons of field use on fly control programs, it is apparent that for qualitative sampling of fly populations, the attached-bait pan trap can readily supplant the larger model device. Although the smaller amount of bait employed by the attached-bait pan trap results in a lesser volume of flies collected, the numbers procured are sufficient for evaluative analysis.

Advantages of the attached-bait pan trap over the other types are that it is smaller and can be disassembled, thereby permitting ease of handling in transportation, in killing and removing specimens, and in storage. In addition, suspension of the trap from trees or fences augments the number and types of locations where the device can be utilized. In large scale operations, the lesser quantity of bait required per unit also is an advantage. On a cost basis, the attached-bait pan trap can be constructed at less expense than the standard size metal fly trap. Because of current fluctuations in the cost of metal supplies, it is impossible to quote a price which can be considered standard. As late as February, 1952, however, an order of 30 traps was completed at a cost of $5.50 per unit.

At present, the attached-bait pan trap is being used successfully at CDC installations to sample fly populations qualitatively and to collect specimens for virologic analysis and for fly dispersion studies. The detailed work plan for this trap can be secured by writing to: Officer in Charge, Communicable Disease Center, U. S. Public Health Service, 50 Seventh Street, N.E., Atlanta, Georgia.

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Attractants for the Green June Beetle with Notes on Seasonal Occurrence[1]

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While observing bait pails during the summer of 1949 in peach orchards in Spalding County, Georgia, it was noted that adults of the green June beetle, *Cotinus nitida* L., were attracted to a bait used for the oriental fruit moth. The green June beetle has been long regarded as a nuisance on ripening fruits, especially peaches, figs, and bunch grapes and many requests have been received for control measures. The larval stage of this insect is recognized as a pest in pastures, lawns, and golf greens. With the recent trend toward increased pasture acreage in the state the damage of the green June beetle may become even more serious. Observations during the last three years indicate this insect is on the increase. On several occasions this insect has been observed literally swarming over pasturelands.

Apparently the oriental fruit moth bait, which contains terpinyl acetate and malt extract as the principal ingredients, has not been reported as an attractant for the green June beetle. Frost & Dietrich (1929) reported that *Cotinus nitida* L. was captured in moderate numbers from July 10 to August 28 near Arendtsville, Pennsylvania, during the seasons of 1926, 1927, and 1928. Traps suspended in peach trees consisted of fermenting sugar or molasses solutions placed in No. 10 tin pails. According to Muma (1944) in Maryland, technical caproic acid is an effective attractant for this insect. Data collected showed that a total of 1168 beetles were caught in two traps operated from June 28 to August 14. Caproic acid diluted 50 per cent with light white mineral oil to reduce the rate of evaporation was also used.

Table 1.—Number of green June beetles collected in peach orchards, using two baits, Spalding County, Georgia, 1949–1951.

	Codling Moth Bait			Oriental Fruit Moth Bait		
Orchard	1949	1950	1951	1949	1950	1951
	Number	Number	Number	Number	Number	Number
Gaissert	3			1148		
Prothro	36	676	9	1533	1635	513
Station	84	158	28	1474	1281	813
Weldon		765			1621	
Total	123	1599	37	4155	4537	1326

METHODS AND MATERIALS.—In the study conducted at Experiment, Georgia, two baits, referred to as the oriental fruit moth and the codling moth baits, were compared for three years. The oriental fruit moth bait, slightly modified from Rosenstiel (1949), consisted of 2.4 pounds malt extract, 14 grams terpinyl acetate, 8.5 grams bentonite, and 5.7 grams of benzoate of soda, in 5 gallons of water. The codling moth bait was prepared by adding bentonite soaked in one pint of water plus 20 ml. anethole to 38 grams benzoate of soda, one quart of molasses, and 5 gallons of water. Both stock materials were diluted to about 1 to 3 with water and used in No. 5 tin pails suspended in peach trees. The bait was replenished when necessary because of evaporation or dilution by rain.

During the three seasons, pails were observed for the following periods: May 3 to November 1, 1949; May 3 to September 28, 1950; and April 30 to October 18, 1951. Pails were examined twice a week and the adult green June beetles were removed and counted each time. On many occasions during examination, beetles were observed to escape, and more could have been collected except for the fact that the pails became full of beetles.

RESULTS AND DISCUSSION.—Table 1 shows the number of beetles caught in pails located in peach trees of four orchards during the three years. It will be noted that fewer beetles were collected in the pails in 1951. This was due to the fact that ⅜ inch hardware cloth was used to exclude the green June beetles which, because of their number, often inter-

[1] Paper No. 224, Journal Series, Georgia Experiment Station, Experiment, Georgia.

fered with the count of other peach insects. However, some beetles managed to enter the wire barrier. Two pails, located in the Station orchard, not covered with the hardware cloth and containing the oriental fruit moth bait collected 7660 beetles. This gives an indication of the number of beetles present in the orchard.

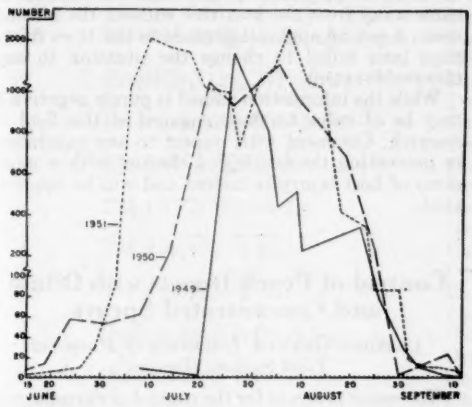

FIG. 1.—Number of adult green June beetles collected in bait pails in peach orchards, Spalding County, Georgia, 1949–51.

Beetles of both sexes were attracted to the bait pails. Examination of 200 beetles, selected at random from specimens collected during July and August 1950 and preserved in alcohol, showed about 60 per cent males and 40 per cent females.

The seasonal occurrence of adult green June beetles as determined by bait pail collections for the three years is presented in figure 1. The earliest date that a beetle was collected in a bait pail was May 15, 1950. Beetles were collected as late as September 23, 1951. However, the period of greatest activity was between July 1 and August 20. Records indicated a relationship between rainfall and the time of emergence, with more beetles emerging after a heavy rain which thoroughly wet the soil. However, rainfall records were not available for each peach orchard where the pails were located so this fact was not established.

To determine the effectiveness of the oriental fruit moth bait near pastureland, a 50-pound lard can containing this bait was observed from July 19 to August 24, 1950. A total of 2172 beetles were collected in the can in slightly over a month.

A preliminary study was made during 1949 to determine whether the complete formula of the oriental fruit moth bait was necessary or whether the fermenting malt alone would attract the beetles. Limited observations of several pails located in fig trees and also on the edge of a pasture indicated that the complete bait containing the terpinyl acetate was more effective than the malt alone. This was studied further during 1951. Two pails containing each of the two baits were compared in a peach orchard. In one set of pails the complete oriental fruit moth bait was used, while in the other pails a bait of only malt extract, benzoate of soda (to slow the rate of fermentation) and water was used. Pails were observed from June 30 to October 18. A total of 7660 beetles were collected in pails containing the complete oriental fruit moth bait and 9334 in pails containing the malt bait. Results show that the malt bait is highly effective as an attractant for this insect and terpinyl acetate is not needed in the formula.

The use of bait pails may serve as an aid in reducing the infestation of the green June beetle on ripe fruit when insecticide control cannot be practiced. Pails containing the malt bait may be suspended in peach or fig trees, and grape vines. Also, bait pails may supplement other control measures and have application around pastures and golf courses. The malt bait is recommended because the ingredients are readily available and the stock material is easily prepared.

SUMMARY.—Emergence of the green June beetle was studied for three years by collecting adults in bait pails suspended in peach trees. Two baits were compared. One consisted of anethole and molasses as the attractants and the other contained terpinyl acetate and malt extract. The latter bait was considerably more effective in attracting this insect. Further study showed that a bait consisting of only malt extract, benzoate of soda, and water was as effective as the complete bait containing terpinyl acetate. The period of greatest emergence of the beetles was between July 1 and August 20. Both male and female beetles were attracted to the bait pails. The use of bait pails containing the malt bait is suggested as an aid in reducing infestation of this insect on ripe fruit. Bait pails may have further application as a supplemental control measure around pastures, lawns, and golf courses.

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Tick Paralysis: A Note on a Human Case Caused by a Male Tick[1]

JOHN H. BROWN[2]

On June 10, 1940, Mr. G. D. R., a 20-year-old employee of the Alberta Department of Public Health visited the heavily tick-infested area around Manyberries for the purpose of making a spotted fever tick (*D. andersonii*) survey. He had been protected against spotted fever by a series of three inoculations ending on May 18, 1940. As he had served two previous years on the survey he was well acquainted with the necessity for carrying on nightly examinations of his person in order to remove any attached ticks as a protection against tularemia and tick paralysis and, by all accounts, faithfully carried out the routine.

June 10, 11, 12, and 13 were spent dragging for ticks in the Manyberries area. On the morning of June 12 Mr. G. D. R. complained of feeling unwell with a soreness in the left arm. He described the soreness as being a heaviness similar to that following the inoculation. However, he was able to con-

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tinue working. No medication or treatment was applied.

On June 13 the condition persisted and great difficulty was experienced in using the arm. This state continued until about 2 P.M. when the soreness suddenly abated and the arm felt normal. That evening a thorough search of the body was conducted by Mr. G. D. R. and the author and a male tick was found firmly attached amongst the hairs of the left axilla. The tick was removed and the wound treated with iodine. The tick was sent on June 16, as collection No. 1-33-40, to Dr. R. J. Gibbons, Dominion Virological Laboratory, Kamloops, B. C., for examination as to its ability to cause paralysis in experimental animals. No report was received.

On June 15 the arm again became noticeably sore and Mr. G. D. R. visited Dr. V. Swancesky of Lethbridge for an examination but nothing of importance was found. During the night of June 15 he became very ill with considerable stomach pain accompanied by a sharp pain in the region of the left diaphragm which caused difficulty in breathing.

On June 16 Mr. G. D. R. visited Dr. S. M. Schmaltz of Lethbridge who gave him a thorough examination and expressed the opinion that he had suffered a mild attack of tick paralysis.

No further difficulty was experienced.

CONCLUSION.—It is believed that the tick became attached to Mr. G. D. R. on June 10 and had been feeding for approximately 48 hours before the left arm became sore and difficult to manage. It is assumed that the sudden cessation of pain on the afternoon of June 13 coincided with the termination of the feeding activities of the male tick. The resumption of pain accompanied by illness on June 15 was probably in the nature of a relapse.

A search of the available literature fails to yield any information on male ticks being associated with human tick paralysis.

Effect of Naphthyl Acetic Acid on Cherry Fruiting

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An attempt is being made by the California Department of Agriculture to eradicate an incipient infestation of the cherry fruit fly, *Rhagoletis cingulata*, infesting domestic cherries in an isolated noncommercial area in the northern part of the state. An integral part of the program involves preventing fruiting by any of the host cherry trees scattered throughout the control area.

It was the concensus of opinion of those authorities with whom the problem was first discussed that this might best be accomplished through the use of napthyl acetic acid applied as a spray after bloom had been complete. While no information could be developed covering the use of this material on cherries it had apparently been successfully used as a thinner on apples and peaches. On these fruits it had been used at 10 ppm. to set fruit and at 30–40 ppm. as a thinner. It was believed that at 100 ppm. it should cause a one hundred per cent drop in the case of cherries if used as previously stated.

The result of its use under these conditions was, however, just the opposite of that intended. The application of the material at 100 ppm. produced a completely hyponastic effect on the foliage, but so far as could be determined did not in any way affect the quantity or quality of the fruit. Any failure of late blooms to set fruit could not be attributed to the application of the material nor was there any apparent dropping of the newly set fruit. Later when it became necessary to hand pick the fruit the pulp of some of the more mature fruits came away from the host tree without the pit and stem. A second application made to test-trees thirty days later failed to change the situation to any observable extent.

While the information gained is purely negative it may be of value to those engaged in this field of research. Comment with respect to any experience in preventing the fruiting of cherries with a minimum of host injury is invited and will be appreciated.

Control of Peach Insects with Dilute and Concentrated Sprays

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The spray program for the control of curculio, oriental fruit moth and insects that cause cat-facing on peaches, has given satisfactory results in most Maryland orchards since benzene hexachloride, DDT and parathion have been incorporated in the spray schedules. Other insecticides, such as TM-1, TM-2 and dieldrin, have given excellent control of some of these pests when used either experimentally or commercially. Even with the effectiveness of these new insecticides, the constant increase in the cost of producing high quality fruit has posed a serious problem to the fruit industry. Because of increased costs, fruit growers are seeking ways of cutting down the expense of spraying, and at the same time maintaining a high degree control of pests. The industry in general has shown increased interest in the new types of spray machines, many of which are designed to apply either dilute or concentrated sprays.

The spray machine used in the experiments reported here is a 1951 model having an air blast with two side delivery of 42,800 cubic feet per minute at 90 miles per hour. The machine is mounted on a truck which is equipped with a speedometer. The sprays were applied with the machine driven at 2.5 miles per hour and the nozzles adjusted to deliver approximately 4 gallons per tree with the dilute, and 1.2 gallons with the concentrate per application. All spraying was done during the day and each spray was applied when due regardless of wind velocity.

Asquith (1950) obtained good control of plum curculio using four times the standard spray concentration and applying from one-fifth to one-fourth the amount required for the dilute sprays. The data in this paper deals primarily with the control of curculio, oriental fruit moth and insects that cause catfacing on peaches with dilute and concentrated spray applications.

The orchard selected for the experiments consisted of 8 year old Elberta trees which were in a state of high vigor. The insect population the previous year was extremely high, resulting in a loss of over 50 per cent of the harvested fruit. Thirteen plots, 3 rows wide and 15 trees deep, were used in the tests. Eight plots were used to make a direct comparison between the dilute and 3× concentration of the same insecti-

Table 1.—Control of peach insects with dilute and concentrated sprays.

PLOT NO.	MATERIAL AND AMOUNTS PER 100 GALLONS		PER CENT CAT-FACING	PER CENT CURCULIO	PER CENT ORIENTAL FRUIT MOTH	PER CENT INFESTED FRUITS
1	Dieldrin[1] 18.5% emulsion*—1 qt.	Harvest	0	4.0	1.0	5.0
		Drops	0	0	0	0
1A	Dieldrin 18.5% emulsion†—3 qts.	Harvest	0	3.0	0	3.0
		Drops	0	.4	0	.4
2	Parathion[2] 15% WP—1 lb.	Harvest	0	0.0	0	0
		Drops	0	0.0	0	0
2A	Parathion 15% WP—3 lbs.	Harvest	2.0	3.0	0	5.0
		Drops	1.1	0.0	0	1.1
3	TM-1 27% WP—1 lb.	Harvest	0.0	4.0	1.0	5.0
		Drops	1.2	.6	0.0	1.8
3A	TM-1 27% WP—3 lbs.	Harvest	1.0	3.0	0.0	4.0
		Drops	2.2	.5	0.0	2.7
4	TM-2 33.4%—1 pt.	Harvest	1.0	1.0	0.0	2.0
		Drops	1.5	0.0	0.0	1.5
4A	TM-2 33.4%—3 pts.	Harvest	1.0	0.0	0.0	1.0
		Drops	1.7	0.0	0.0	1.7
5	Dieldrin 25% WP*—2 lbs.	Harvest	1.0	0.0	0.0	1.0
		Drops	0.0	0.0	0.0	0.0
6	Dieldrin 25% WP*—2 lbs.	Harvest	2.0	0.0	0.0	2.0
		Drops	.6	0.0	0.0	.6
7	TM-3 32.1%—1.5 pts.	Harvest	4.55	12.5	11.36	28.41
		Drops	2.3	7.71	0.0	10.01
8	TM-3 32.1%—1.5 pts.	Harvest	16.10	24.20	58.0	99.90
	Applied to soil only	Drops	2.89	39.33	0.0	42.22
9	Check, sprayed with fungicide only	Harvest	27.87	12.66	54.43	94.53
		Drops	4.97	28.60	0.0	33.57

* 2 lbs. 50% DDT paste added to 1st and 3rd applications.
† 6 lbs. 50% DDT paste added to 1st and 3rd applications.
1—Dieldrin 21.2%).
2—Parathion (0,0-Diethyl 0-p-nitrophenyl thiophosphate 15%).
TM-1—(EPN (Ethyl P-Nitrophenyl Thioobenzenephosphonate 27%).
TM-2—(Metacide (parathion (0,0-diethyl 0-p-nithophenyl thiophosphate 6.2%; 0,0-dimethyl thiophosphate 24.5%; Related organic phosphates 2.7%).
TM-3—Systox (E-1059 (a trialkyl thiophosphate 32.1%).

cide. The remaining plots were sprayed with dilute applications.

Each plot received 5 applications of insecticides applied on the following dates: April 27, May 12, 17, 28 and July 16, with the latter being timed against the second brood curculio. Six pounds of sulfur per 100 gallons of spray were added to each dilute, and 18 pounds to each 3× concentrate. On August 20, all plots were treated with a concentrated spray of 6 quarts of liquid lime sulfur to each 100 gallons for the control of brown rot.

Records on fruit injury were taken from all of the drops and harvested fruit from four trees in the center of the middle row from each plot. These trees were selected because they were subjected to the least amount of drift from the other plots. The data obtained on the control of insects are shown in table 1.

DISCUSSION.—The insecticides used in these experiments were DDT, parathion, dieldrin emulsion, dieldrin powder, TM-1, TM-2 and TM-3. A study of the data in the table shows that the materials used in all of these schedules, except TM-3, gave control of the insects involved. There was practically no difference in results obtained between the dilute and 3× concentrate applications. TM-3 was the only material that caused any injury to the foliage or fruit, and it proved ineffective in the control of pests involved in these tests when applied as a ground treatment or sprayed on the foliage.

CONCLUSION.—One year's experiments in comparing the effectiveness of dilute and 3× concentrate sprays on the control of peach insects indicate that both methods were effective under the conditions that existed in this orchard. Parathion and TM-1 proved effective against curculio, oriental fruit moth and insects that cause cat-facing. Dieldrin emulsion, dieldrin powder and TM-2 were effective against the above insects when DDT was added to the first and third spray applications. TM-2 was ineffective against the insects involved in these tests and caused injury to both fruit and foliage.

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Comparison of High and Low Spray Pressures for Control of Cattle Grubs

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The use of a power sprayer for the control of cattle grubs was first recommended in 1942. Wells (1942) found that sprays of cube or derris applied at a pressure of 250 pounds per square inch gave satisfactory control of *Hypoderma lineatum* (DeVill.). Since that time power sprayers have been widely used in the treatment of livestock for grub control, but unfortunately, many conflicting recommendations for pressures, formulations, and application techniques have arisen.

The Bureau of Entomology and Plant Quarantine recommends a pressure of 400 to 500 pounds for applying derris or cube sprays (Bishopp *et al.* 1949). Shull *et al.* (1945) recommend a minimum of 400 pounds for the control of cattle grubs in Idaho. Stewart (1944) recommends 250 to 300 pounds' pressure for the control of *Hypoderma lineatum* in California. Scharff (1950) found that in Montana a pressure of 400 pounds was necessary for satisfactory control of *H. lineatum*, but that a pressure of 600 pounds gave only 80 per cent control of *H. bovis* (L.). He also found that the timing of the application was as much a factor in obtaining a high kill as was the method. In areas where the grubs reached the animal's back in late summer the time required for them to emerge from the cyst was as much as 3 weeks longer than where the grubs reached the back in late winter.

In the Kerrville, Texas, area in 1951 heavy populations of third-stage larvae were found in the backs of cattle as early as August 25, and both second- and third-stage larvae were found in the back of one animal on July 26. Grubs continued to emerge until late in February. This early emergence contributed to the mounting volume of complaints from stock growers that good grub control with the present recommendations was hard to obtain.

In 1950 and 1951 a series of tests were conducted in the vicinity of Kerrville to compare spray pressures of 200 and 400 pounds per square inch for the control of cattle grubs in the Southwest, where they normally emerge during the late summer and early winter months. Since many of the livestock growers possess small sprayers, it was deemed advisable to obtain as much information as possible on the kill of grubs by spraying with machines capable of maintaining not more than 200 pounds' pressure.

METHODS AND MATERIALS.—As these tests were to be conducted on the same basis as the livestock grower would conduct his spray program, herds were selected that could be easily handled for spraying and were accessible for examination after treatment. During the two seasons, tests were made on 12 herds of Hereford, Brahman, and Angus range cattle of all ages. In all the herds the grub population was heavy. Each herd was examined before treatment and divided into two groups having as nearly as possible the same number of grubs.

Sprays containing 7.5 pounds of cube or derris (rotenone 5 per cent) per 100 gallons of water were applied with a power sprayer capable of maintaining pressures up to 600 pounds per square inch. One gallon was applied to each animal with a three-nozzle gun held vertically 12 to 18 inches above its back. Nozzles with 0.03-inch orifice, carrying No. 3 discs, were used. The animals were crowded into narrow chutes so that the operator could work from the top of the chute above the animals. One week after the treatment all grubs were squeezed from the cysts and examined for mortality. First-stage larvae were disregarded, since many of them moved into the backs of the animals after treatment, but 3000 second- and third-stage grubs were examined.

Each group of animals was sprayed only once in a season. The application was timed so as to have as many grubs in the backs as possible. The spray applications were started in October and continued until late in December, when the hair coat was short and thin, and no difficulty was experienced in wetting the animal's back. It seems probable that in northern areas penetration of the winter hair coat would be much more difficult with that amount of spray because of the density of the hair.

RESULTS.—The results obtained in these tests are shown in table 1. The mortality of recovered grubs varied in each group of sprayed animals, but the range and average were about the same for both groups. It appears that spraying with derris or cube will give only a partial kill of the grubs present in the backs of the animals at the time of application, regardless of the spray pressure used.

Table 1.—Number of grubs recovered and per cent mortality of the second- and third-stage cattle grubs sprayed at pressures of 200 and 400 pounds per square inch.

200 POUNDS		400 POUNDS	
Grubs Recovered	Per Cent Mortality	Grubs Recovered	Per Cent Mortality
120	63	118	69
93	64	39	80
82	78	119	65
137	75	164	80
180	56	132	67
185	52	314	65
88	85	169	64
49	90	92	89
104	88	90	89
119	88	95	78
47	84	77	88
47	83	161	76
Average	76	Average	76

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Control of Yellow-Striped Armyworm on Cotton with Organic Insecticides[1]

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For many years the yellow-striped armyworm, *Prodenia ornithogalli* Guen., has been recognized as a pest of cotton and many other crops, but has seldom caused economic damage in the Mississippi Delta. The species winters in the pupal stage in the soil and has several generations a year. The females lay their eggs in masses on the foliage of plants and trees, on buildings, and other outdoor environments. The egg masses are covered with scales from the body of the female moth, making them inconspicuous and hard to find.

Soon after hatching the young larvae migrate to nearby vegetation and become voracious feeders. The caterpillars are commonly olive-green or greenish brown in color, have two dorsal, triangular, black spots on most of the segments, and characteristic bright orange stripes just outside these spots on each side of their bodies. The adults measure about 1⅝ inches from wing tip to wing tip, and are dark to light grayish brown moths with irregular white markings on their outer wings. The caterpillar is a day-feeding species that is sometimes very destructive to cotton, devouring the young plants as well as boring into squares and bolls of older plants.

During the spring and summer of 1951 the yellow-striped armyworm occurred in large numbers of widespread acres in the Mississippi Delta, causing considerable damage, especially to young cotton early in the season. Numerous inquiries were received as to the effectiveness of the new synthetic organic insecticides against this pest.

Folsom (1932) recommended the use of calcium arsenate and bran baits for control of this insect. Metcalf *et al.* (1951, pp. 402–407) suggested dusting the host plants with 5 to 10 per cent of DDT or TDE (DDD), sufficient benzene hexachloride to give 2 per cent of the gamma isomer, cryolite or calcium arsenate for control of species of cutworms that feed above the ground. However, the search for specific recommendations for control of the yellow-striped armyworm revealed little recently published information on this subject.

As a result two experiments involving 11 of the new insecticides were initiated on July 5, 1951. The main objective was to determine the relative effectiveness of two dosage levels of these chemicals for the control of the yellow-striped armyworm under field conditions.

A field of young cotton located on the Delta Branch of the Mississippi Agricultural Experiment Station at Stoneville was selected for these experiments. Rows were marked off into 25-foot sections for the various treatments. The cotton plants ranged from 10 to 14 inches in height.

The different experiments were run concurrently to study the relative effectiveness of different dosage levels on control. A hand-operated knapsack sprayer equipped with a nozzle that delivered a cone-shaped spray at the rate of 1 gallon per hour was used to apply the insecticides. All the insecticides tested were emulsion sprays prepared from emulsifiable concentrates supplied by the manufacturer or formulator.

Immediately after the sprays were applied, four cylindrical screen-wire cages, equipped with cheesecloth covers and metal bases so that they could be depressed below the soil surface, were set over plants in the treated and untreated plots. Ten larvae, ranging in size from approximately one-third to nearly full grown, were then released in each cage. Observations to determine mortality were made after 22, 42, and 90 hours.

RESULTS.—Table 1 shows that the yellow-striped armyworm was resistant to most of the chlorinated hydrocarbon insecticides and in general was much harder to kill than many of the other lepidopterous larvae commonly found on cotton. EPN, the only organic phosphate used in the test, was by far the most effective insecticide. At the low-dosage levels,

Table 1.—Results of tests with organic insecticides applied at different dosage levels for control of the yellow-striped armyworm on cotton.

INSECTICIDE	POUNDS OF TOXICANT PER ACRE	PER CENT OF LARVAE DEAD OR PARALYZED AFTER— 22 Hours	42 Hours	90 Hours
Low-Dosage Level				
Aldrin	0.08	0	0	15
Chlordane	.17	0	16	30
Compound 269[1]	.03	7	17	67
Compound 711[2]	.03	0	3	8
DDT	.17	5	16	33
Dieldrin	.05	2	7	30
EPN	.10	85	95	100
Heptachlor	.08	2	2	3
Lindane	.10	2	5	13
TDE	.17	5	24	48
Toxaphene	.33	34	59	78
Check (no treatment)		0	0	0
High-Dosage Level				
Aldrin	.17	5	40	49
Chlordane	.33	2	16	42
Compound 269	.07	5	13	37
Compound 711	.07	0	3	3
DDT	.33	14	51	67
Dieldrin	.10	18	43	70
EPN	.20	100	100	100
Heptachlor	.17	3	5	11
Lindane	.20	8	16	17
TDE	.33	14	43	89
Toxaphene	.83	55	72	78
Check (no treatment)		0	0	0

[1] A stereoisomer of dieldrin.
[2] A stereoisomer of aldrin.

0.10 pound of EPN, 0.33 pound of toxaphene, and 0.03 pound of compound 269 applied to small plants at the rate of 1 gallon of spray per acre gave excellent, satisfactory, and substantial control, respectively. Increased dosages of the chemicals showed that 0.20 pound of EPN, 0.33 pound of TDE, 0.85 pound of toxaphene, and 0.33 pound of DDT gave perfect, good, satisfactory, and substantial control, respectively. For some unexplainable reason compound 269 was not nearly so effective at 0.2 pound per acre as at the 0.1-pound rate.

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[1] The investigations were made in cooperation with the Delta Branch of the Mississippi Agricultural Experiment Station. Certain phases of this study were carried on under the Research and Marketing Act of 1946.
[2] Special thanks are extended to E. W. Dunnam, under whose general direction the studies were made.

Flat, Hollow, and Solid Cone Nozzles for Earworm Control[1]

L. P. DITMAN, GEORGE BURKHARDT, and D. T. BLACK[2]

Blanchard *et al.* 1950, in the original description of power spraying equipment for the control of the earworm, specified flat, weed-control type spray nozzles, with 40 to 45 degree spray angles, to be used 4 per row. These flat spray nozzles have an advantage over cone nozzles in that they tend to give a uniform distribution of insecticide over the entire width of the spray band. On the other hand, cone nozzles could conceivably give better coverage because the corn plant is sprayed from two directions, the front edge of the cone striking at a forward angle, the back edge at a backward angle. Solid cone nozzles should tend to have the advantages of both the hollow cone and flat nozzle.

It was also thought that there should be a relation between the width of the spray band and the spray dosage. If ear height was sufficiently uniform to permit narrowing of the spray band pattern then the per acre dosage could be reduced.

Though all of these factors were not thoroughly tested, several experiments were conducted, comparing the flat 40 degree nozzle with the hollow cone 75 degree and the solid cone 30 degree nozzles, all being used on similar booms with four nozzles per row. In addition two solid cone 50 degree nozzles per row were compared with four flat nozzles per row.

In all, three experiments were conducted in each of which two types of nozzles were compared The different treatments were replicated 6 to 10 times in each experiment; the number of untreated checks, as they were unimportant to the conclusion of the work, was reduced in all except one experiment. Six-row plots were replicated, but not randomized, in rather large fields of Country Gentleman type, white canning sweet corn. At harvest, 125 plant samples were taken from inside rows. All ears were pulled, the number, weight in husk, and husked weight of clean and infested ears and nubbins recorded. While a light infestation of fall armyworm was present, this insect is almost completely eliminated by DDT sprays, so that all injury to ears was recorded as earworm or European corn borer, provided the latter was present. Two categories of earworm infestation were recorded—ears with larvae present and ears injured to the extent

[1] Scientific Article No. A363, contribution No. 2348 of the University of Maryland Experiment Station, Department of Entomology. Report of a study in which certain phases were carried on under the Research and Marketing Act of 1946.

[2] Ditman, Department of Entomology; Burkhardt, Department of Agricultural Engineering, University of Maryland; D. T. Black, Bureau of Plant Industry, Soils and Agricultural Engineering, Division of Agricultural Engineering, U.S.D.A.

Table 1.—Comparison of flat and solid cone nozzles, 4 per row, treatments replicated 10 times, with 4 untreated checks. Two applications of all treatments.

Treatment	Total No. Ears	Total Lb. in Husks	Per Cent Infested			Total Lbs. of Husked Ears		
			Corn Borer	Ear-worm	Severe Earworm	Clean	Injured	Nubbins
Flat nozzles	1153	591.8	2.5	22.8	1.9	319.5	94.1	13.5
Solid cone nozzles	1139	559.6	1.8	25.1	2.9	299.9	94.3	18.7
Check[1]	1142	535.0	8.5	72.4	42.0	75.7	301.5	18.7

[1] Check results adjusted to 10 replicate basis: average of check result ×10.

Table 2.—Comparison of flat and hollow cone nozzles, 4 per row, treatments replicated 10 times, with 4 checks. Two applications of all treatments.

Treatment	Total No. Ears	Total Lb. in Husk	Per Cent Infested			Total Lbs. of Husked Ears		
			Corn Borer	Ear-worm	Severe Earworm	Clean	Injured	Nubbins
Flat nozzles	1103	443.6	1.4	38.7	9.0	179.8	128.4	10.1
Hollow cone nozzles	1180	441.8	1.3	44.4	8.7	167.5	144.0	8.1
Check[1]	1137	485.5	3.9	91.8	74.2	11.5	320.0	14.2

[1] Check adjusted to 10 replicate basis: average of check result ×10.

Table 3.—Comparison of four 40-degree flat nozzles per row with two 50-degree solid cone nozzles per row, all treatments replicated 6 times, one application of each spray.

Treatment	Total No. Ears	Total Lb. in Husk	Per Cent Infested			Total Lbs. of Husked Ears		
			Corn Borer	Ear-worm	Severe Earworm	Clean	Injured	Nubbins
Solid cone nozzles	663	304.5	2.8	82.5	46.3	31.7	187.3	10.6
Flat spray nozzles	678	303.2	3.8	83.4	45.1	28.6	185.6	13.6
Check	718	315.1	5.4	92.6	88.7	0.8	224.4	9.4

that trimming would be required in the normal canning operation. The insecticide used was a proprietary product containing mineral oil and DDT which was diluted 1 part with 9 parts of water. This gave a DDT content of finished spray equivalent to five pints of 30 per cent emulsion in 25 gallons. All applications were made at 32±2 gallons of spray per acre.

From observation of the spraying operations with the different nozzles it appeared that the four narrow angle solid cone nozzles per row applied the heaviest deposits of spray on the ear region of the corn plant. The wide angled hol ow cone nozzles appeared to leave the lightest deposit and were the least penetrating, as the spray cones break rather close to the nozzle so that the full velocity of the spray stream is lost before striking the plant. The flat nozzle gave a coarse large particle spray that was most penetrating. With all types of nozzles spraying horizontally or nearly so, the heaviest deposits of spray were in the lower portions of the spray patterns, caused by the heavy downward drift of larger spray droplets.

Results (Tables 1 to 3) did not show superiority of hollow cone or either of the solid cone nozzles over the flat spray type usually recommended. Earworm control was poorer with the wide angle hollow cone nozzles than with the flat type but differences were not statistically significant. Total weight of ears at harvest was neither significantly increased nor decreased as compared with unsprayed yields. There was likewise no significant difference in the percentage of nubbins.

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Effectiveness of Allethrin and Pyrethrins as Sprays against Three Species of Mosquitoes

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In early work on the evaluation of allethrin as an insecticide (Fales *et al.* 1951), it was shown that, in kerosene-base sprays at low concentrations against adults of *Anopheles quadrimaculatus* Say, this material was more effective than pyrethrins in knock-down but less so in kill. At an increased dosage against this species, as well as against *Aedes aegypti* (L.), satisfactory performances resulted. Nagasawa *et al.* (1951) found that allethrin in an incense was about one and one-half times as effective as the pyrethrins in knock-down against adult *Culex pipiens* var. *pallens* Coq.

It is known that allethrin at conventional house fly dosages readily controls mosquitoes. However, it was still thought necessary to study further the use of allethrin against adult mosquitoes.

To obtain dosage-mortality data sprays containing allethrin or pyrethrins were used against free-flying laboratory-reared *Aedes aegypti* (L.), *Anopheles quadrimaculatus* Say, and *Culex pipiens* L. in a Peet-Grady chamber. The insects were liberated into the chamber before various dosages of spray were released. There were up to seven replicates with approximately 80 mosquitoes per test. The *Aedes* were exposed for five minutes and collected after ten more minutes, during which time the chamber was being ventilated, while the other two species were exposed for ten minutes and collected immediately after the exposure. In these tests the insects were divided by sex when the mortality counts were taken. Moribund insects were considered alive. The sex of the knocked-down insects was not determined. The results of the experiments are shown in table 1.

Increased amounts of allethrin were needed to match the mortality caused by the pyrethrins. It has been common knowledge among workers using mosquitoes as test insects that the males are much less resistant to insecticides than are the females. This was pointed out by Waterhouse (1947). The results given here show that this was true in every test.

When the mortality figures for *Aedes* females were plotted, it was found that the LC-50 of allethrin was eight times that of the pyrethrins. With *Anopheles* twice and with *Culex* approximately five and one-half times the amount of allethrin was required.

Against male *Aedes*, the amount of allethrin required was again eight times that of pyrethrins.

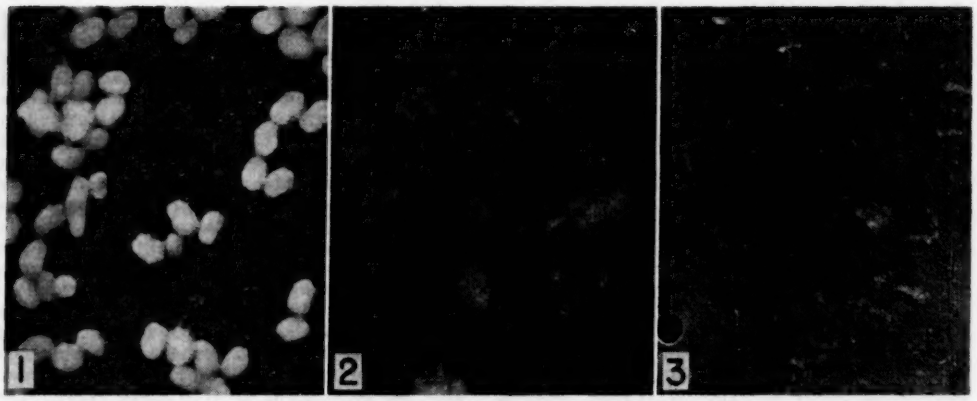
Table 1.—Comparison of effectiveness against adult mosquitoes of allethrin and pyrethrins in kerosene sprays.

MATERIAL	CONCENTRATION (Mg. per ml.)	KNOCK-DOWN IN 10 MINUTES	KILL IN 1 DAY	
			Males	Females
Aëdes aegypti (13.89 ml. per 1,000 cu. ft.)				
Allethrin	0.132	High	48%	30%
	.264	High	72	40
	.528	High	93	66
	1.056	High	99	93
Pyrethrins	.033	High	76	50
	.066	High	93	70
Anopheles quadrimaculatus (9.26 ml. per 1,000 cu. ft.)				
Allethrin	0.2	Medium	52	0
	.4	High	92	32
	.8	High	95	54
	1.6	High	100	73
Pyrethrins	.2	High	68	28
	.4	High	85	41
	.8	High	100	85
Culex pipiens (9.26 ml. per 1,000 cu. ft.)				
Allethrin	3.2	High	94	45
	6.4	All	96	84
Pyrethrins	.2	High	20	2
	.4	High	70	40
	.8	High	86	74
	1.6	High	91	82

With *Anopheles* the materials gave nearly equal performances. With *Culex* the lowest concentration of allethrin (3.2 mg./ml.) gave approximately the same results as the highest concentration of pyrethrins (1.6 mg./ml.).

The knock-down was satisfactory with the allethrin sprays in each test, but it should be pointed out that, except for the tests with the *Anopheles*, the lowest concentration of allethrin was much greater than that of the pyrethrins.

The relative resistance to insecticides of the three species of mosquitoes tested was clearly shown. The *Aedes* mosquitoes were the least resistant and the *Culex* were the most resistant, while the *Anopheles* were intermediate between the two. Waterhouse (1947) found the same relationship, using different



EXPLANATION OF FIGURES

Electron micrographs of the granules and virus particles of the granulosis of the western grape leaf skeletonizer. All preparations shadowed with palladium.

FIG. 1.—Untreated granules. Each of these bodies normally contains a rod-shaped virus particle.

FIG. 2.—Granules after treatment with 0.1 N sodium carbonate for three minutes. Virus particles are visible, embedded in the mass of partly dissolved granules.

FIG. 3.—Virus particles freed of the granule material by dissolving granules in 0.05 N sodium carbonate —0.05 N sodium chloride for three hours. The appearance of the particles and their measured width suggest that they may still be enclosed in a membrane.

species but of the same genera as used here. This information is of considerable importance as to control procedures for adult mosquitoes when sprays are being used, especially when there are shortages in certain insecticides.

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A Granulosis of the Western Grape Leaf Skeletonizer[1]

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During 1950 and 1951, Owen J. Smith and Robert Langston sent our laboratory several lots of larvae of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., reared in an insectary at La Mesa, California. The insectary is being operated by the Division of Biological Control (University of California) for the purpose of rearing parasites of the grape leaf skeletonizer, a pest of wild and cultivated grapes in southwestern United States. A considerable amount of trouble with diseased larvae hampered the rearing operations and prompted the operators to send us infected specimens of the skeletonizer for diagnosis.

According to Smith & Langston (personal communications) diseased skeletonizer larvae were first observed in specimens being reared in the laboratory (then located at Fort Huachuca, Arizona) in late August, 1950. The insects showed evidence of disease coincident with the maintenance of hot, humid conditions in a room where the larvae were being parasitized by the tachinid parasite *Sturmia harrisinae* Coq. Specimens of these larvae were submitted to us for diagnosis, and found to be harboring a sporeforming bacillus, apparently *Bacillus cereus* Frankland and Frankland. The same bacterium was isolated from diseased larvae sent to us in October, 1950, and in May and July, 1951, from La Mesa, California. (The laboratory was moved from Arizona to California in October 1950.) No other infectious agents were found in these larvae.

Beginning in July, 1951, diseased skeletonizer larvae appeared in increasing numbers and soon reached serious proportions. Within a month's time the entire rearing stock (consisting of thousands of larvae crowded together in cages) was threatened, and, in some of the rearing rooms, a mortality of approximately 98 per cent was suffered. The infected larvae representing this resurgence of disease gradually ceased feeding, became flaccid, turned brown in color, and upon dying frequently hung down by their anal prolegs from the sides of the rearing cages or from the grape leaves. Most of the larvae dropped to the bottom of the cages. Eventually the insects dried to a brittle mass remaining brown in color or turning black. Microscopic examination of larvae showing these general symptoms revealed the presence of a granulosis virus. Subsequent lots of larvae confirmed the general presence of the virus in affected larvae throughout the rearing

[1] Contribution from the Laboratory of Insect Pathology, Division of Biological Control, College of Agriculture, University of California, Berkeley 4, California.

rooms. The plight of the rearing operations was alleviated by moving the insectary stock to another location while the insectary itself was thoroughly cleaned and disinfected, and by instituting strict sanitary measures as a routine part of the operations.

The virus concerned is, in general, similar to the other known granulosis viruses (Figs. 1, 2 and 3). There is, however, a somewhat greater variation in the size of the granules than is usually found in similar diseases. As determined from electron micrographs, the granules ranged in length from 167 to 975 millimicrons, while the width varied from 165 to 370 millimicrons. The average size of the granules was approximately 256 by 345 millimicrons. The average size of the virus particles was found to be approximately 67 by 245 millimicrons. The rather great width suggests that the rods seen may not be naked virus particles. Other virus particles have been described as being enclosed within membranes (Bergold 1950; Wasser & Steinhaus 1951) and it is quite possible that the same condition pertains to those photographed and measured here. It will be seen from these figures that occasional granules may be found which are shorter than the virus rods. It has not been demonstrated whether or not such small granules have anything of a virus nature within them. If they contain virus particles, it is obvious that the particles cannot be the normal rod-shaped ones. It is possible, however, that small granules might contain folded forms of the virus such as those described elsewhere (Bergold 1950; Wasser & Steinhaus 1951).

That the virus is probably a new species is indicated by the fact that it was not infectious for the hosts of most of the granuloses so far described. The hosts tested were: the variegated cutworm, *Peridroma margaritosa* (Haw.); the buckeye caterpillar, *Junonia coenia* Hüb.; the salt marsh caterpillar, *Estigmene acraea* (Drury); and the imported cabbageworm, *Pieris rapae* (Linn.).

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Control of the Texas Harvester Ant

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The Texas harvester ant, *Pogonomyrmex barbatus* var. *molefaciens* (F. Smith) lives underground in colonies which usually have only one entrance. These ants kill all types of vegetation within a diameter of 3 to 6 feet of the entrance. In cultivated fields of the Lower Rio Grande Valley the ants are destructive to stands and often will destroy many small seeds before they have a chance to germinate. A survey has shown as many as 30 ant colonies per acre in cultivated fields and citrus orchards. These ant colonies not only destroy the appearance of well kept lawns but the pests are very obnoxious due to their habit of stinging people.

Brett (1950) obtained control of the Texas harvester ant by pouring one quart or more of 3-per cent chlordane down the entrance of each colony. He did not state the length of time that these treated colonies were observed. Both Brett (1950) and Riherd (1948) failed to obtain control of this ant by dusting the surface near the entrance with chlordane, benzene hexachloride or toxaphene dusts.

PROCEDURE.—Only those ant colonies with a minimum number of 25 ants in a foot radius of the entrance were used in this experiment. The treatments, shown in table 1, consisted of adding the desired amount of emulsifiable insecticide to a gallon of water and then pouring it down the entrance of the colony. The colonies were then observed for ant activity for a period of 8 weeks. The first series of colonies were treated September 25, 1951, the second 2 weeks later, and the third 2 weeks after the second.

Table 1.—Control of the Texas harvester ant.

CONCENTRATION INSECTICIDE IN GALLON OF WATER	COLONIES TREATED	PER CENT COLONIES CONTROLLED AT END OF THE WEEKS INDICATED			
		2	4	6	8
0.2% Chlordane	9	78	56	44	44
0.1% Chlordane	4	75	75	50	50
0.05% Chlordane	4	25	0	0	0
0.2% Aldrin	9	100	100	100	100
0.1% Aldrin	4	75	75	25	25
0.05% Aldrin	4	75	75	25	25
0.2% Heptachlor	5	100	100	100	100
0.2% Dieldrin	5	100	100	100	100
0.2% TM-1	5	100	80	80	80
0.2% Toxaphene	5	40	20	20	20
0.08% gBHC	5	20	20	20	20
Untreated	9	0	0	0	0

DISCUSSION.—The data in table 1 shows that 0.2-per cent concentrations of aldrin, heptachlor, and dieldrin were superior to the same concentration of chlordane in controlling the Texas harvester ant. TM-1[3] was more effective than chlordane but was not as effective as aldrin, heptachlor or dieldrin. The data show that the toxaphene and benzene hexachloride treatments are of little value as a control of the Texas harvester ant. The data in the table also show that 0.1-per cent chlordane was just as effective as 0.2-per cent chlordane. Concentrations of 0.05 and 0.1-per cent aldrin controlled 75 per cent of the ant colonies 4 weeks after application but soon lost their residual effectiveness.

Numerous dead ants were seen around the colonies the day following treatments with 0.2-per cent concentrations of aldrin, dieldrin, and heptachlor. It was also observed that numerous dead ants were found around the ant entrances 2 and 4 weeks after treatment application. This indicates the importance of having a residual material which will kill those ants which hatch and develop after the treatment application.

SUMMARY.—Good control of the Texas harvester ant was obtained by pouring one gallon of 0.2-per cent aldrin, dieldrin, and heptachlor down the entrances of the colonies. The same concentrations of chlordane and TM-1 were less effective but did give control. Concentrations of 0.2-per cent toxaphene and 0.08-per cent gamma benzene hexachloride were ineffective.

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[3] TM-1, test material no. 1, 6.2% 0, 0-diethyl 0-p-nitrophenyl thiophosphate plus 24.5% 0,0-dimethyl 0-p-nitrophenyl thiophosphate plus 2.7% related organic phosphates plus 66.6% inert ingredients and called "Metacide" by the manufacturer.

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A Partial Annotated List of Species of the Tabanidae

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Severe outbreaks of blood-sucking flies of the family Tabanidae have been known to occur in certain areas of Texas for many years. In recent years these outbreaks have taken place over larger areas, and the damage inflicted by the attacks of the flies has become a serious problem. These outbreaks of blood-sucking flies spread diseases and cause much irritation to man and animals. Howell *et al.* (1941) showed that anaplasmosis, a serious disease of livestock, could be transmitted among cattle by many different species of tabanids. The biting of these flies, in addition to the disease transmission, causes so much irritation to the animal that grazing is reduced, resulting in loss of body weight and reduced milk production. In many instances the fly bite leaves the way open for screwworm infestations, which often times become fatal to the animal. Transmission of anaplasmosis and anthrax occurs when blood-sucking flies feed on a carrier animal and then on one that is disease-free.

Cattlemen of the Texas coastal region report that horseflies are directly responsible for more than half of the losses in the cattle of that area. In some parts of the Gulf coast region the livestock have to be removed from the pastures during the fly season. Infestation counts of 100 to 200 horseflies and deerflies per animal are not uncommon during the more severe outbreaks. As many as ten species of horseflies have been observed by the authors, feeding simultaneously on one animal. Such infestations may easily result in the loss of one or more pints of blood from an animal per day.

Early in the spring of 1950, adult Tabanidae collections were started in areas of Texas where severe outbreaks were known to occur. In general, most of the species listed here were collected in the eastern portion of the State. Only two species, *Tabanus abactor* Phil. and *Tabanus dorsifer* Walk., were collected in the western portion of Texas. Such species as *Tabanus lineola* F., *T. molestus* Say, *T. sulcifrons* Macq., and *Chlorotabanus crepuscularis* (Beq.) were extremely numerous in the southeastern portion of Texas. Since collecting was done only in those areas where severe outbreaks were known to have occurred in past years, it stands to reason that the following list is far from being a complete listing of the species of the Tabanidae of Texas.

The taxonomic arrangement of the species listed was compiled according to Philip's publication, "A Catalog of the Blood-Sucking Fly Family Tabanidae (Horseflies and Deerflies) of the Nearctic Region North of Mexico." The species collected in the State of Texas are listed.

Tabanidae

Subfamily Tabaninae Loew
- Tribe Chlorotabanini Phil.
  - Genus *Chlorotabanus* Lutz
    1. *crepuscularis* (Beq.)
- Tribe Tabanini Enderlein
  - Genus *Agkistrocerus* Philip
    1. *finitima* (Stone
    2. *megerlei* (Wied.)
  - Genus *Leucotabanus* Lutz
    1. *annulatus* (Say)
  - Genus *Whitneyomyia* Bequaert
    1. *beatifica* (Whitney)
    2. *beatifica* subsp. *atricorpus* Phil.
  - Genus *Hybomitra* Enderlein
    1. *lasiophtha'ma* (Macq.)
    2. *trispila* (Wied.)
  - Genus *Tabanus* Linnaeus
    1. *abactor* Phil.
    2. *abdominalis* F.
    3. *americanus* Forster
    4. *amplifrons* Krober
    5. *atratus* F.
    6. *cheliopterus* Rond.
    7. *cymatophorus* Macq.
    8. *dorsifer* Walk.
    9. *equalis* Hine
    10. *fuscicostatus* Hine
    11. *giganteus* Deg.
    12. *gladiator* Stone
    13. *imitans* Walk.
    14. *lineola* F.
    15. *lineola* subsp. *scutellaris* Walk.
    16. *longus* O. S.
    17. *molestus* Say
    18. *molestus* subsp. *mixis* Phil.
    19. *mularis* Stone
    20. *nefarius* Hine
    21. *nigrescens* subsp. *atripennis* Stone
    22. *nigripes* Wied.
    23. *nigrovittatus* Macq.
    24. *petiolatus* Hine
    25. *proximus* Walk.
    26. *pumilus* Macq.
    27. *punctifer* O. S.
    28. *quaesitus* Stone
    29. *quinquevittatus* Wied.
    30. *stygius* Say
    31. *sulcifrons* Macq.
    32. *texanus* Hine
    33. *trimaculatus* Palisot de Beauvois
    34. *venustus* O. S.
    35. *vittiger* subsp. *schwardtii* Phil

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Larval Habitat of *Tabanus sulcifrons* in Oklahoma[1, 2]

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Tabanus sulcifrons Macq. is widely distributed in the United States, and over much of its range it is recognized as one of the most injurious horse flies. Schwardt (1936), working in Arkansas, found three egg masses fastened to a small branch of an elm tree, and in one locality successfully collected numbers of *T. sulcifrons* larvae in soil ranging from moist to rather dry. He interpreted his findings as suggesting that the larvae did not require much soil moisture and might be intolerant of wet soil. MacCreary (1940) collected five larvae of this species in New Jersey from a plot on which no standing water was ever present.

Tabanus sulcifrons is one of the most abundant horse flies in Oklahoma. Emergence begins late in June and reaches a peak in August. Populations decline in September. This important species is abundant in the vicinity of Stillwater. Published records of larvae collected in the United States are meager, therefore an extensive series of soil samples was taken in the Stillwater area in 1949, 1950, and 1951. The data obtained in Oklahoma are believed to be applicable wherever this species is abundant.

COLLECTING METHODS.—In each new location investigated for the presence of *Tabanus sulcifrons* larvae, an area of 1 square yard was examined. In taking the first samples the soil was removed to a depth of 6 inches, but since the larvae were found to be close to the surface, later excavations were made only about 3 inches deep. Soil samples taken near water were washed through a 16-mesh sieve to remove the soil and expose any larvae present. Samples taken in areas away from water were examined by turning the ground with a shovel and examining the clods. Where the soil was dry and compact the clumps were broken up with a hammer.

Collection records were based on determinations of reared adults until the writer became thoroughly familiar with the specific characters of *Tabanus sulcifrons* larvae. The field-collected larvae were reared individually in jars of damp sand in the laboratory. They were fed twice weekly on earthworms or other annelids found in sewage filter beds. Subsequent records were frequently based only on identification of the larvae, but doubtful specimens were reared to adults for positive identification.

LARVAL HABITAT.—Although thousands of samples of soil were taken from wet areas, *Tabanus sulcifrons* larvae were collected in such areas only once. A single larva—the one positive sample—was taken from permanently wet moss-covered soil near a spring seep.

A total of 255 *Tabanus sulcifrons* larvae were found in 37 different locations, all in well-drained areas. The moisture conditions ranged from damp to extremely dry. It appeared that the only moisture received in those habitats was the result of rainfall. Permanent standing water never was present in those locations.

The larvae were widely scattered throughout each of the habitats. The maximum number found per square yard was four, but in favorable sites the average population was two or three per square yard. The larvae were distributed from just below the surface to a maximum depth of 2 inches, most of them being from 0.5 inch to 1.5 inches below the surface. There was no evidence that they penetrated deeper into the soil to escape desiccation or freezing.

Estivation occurred in short tunnels, flattened at the top and bottom, in the dry soil. During periods between rainfalls, when the soil has become relatively dry, the finding of such tunnels was a definite aid in determining the presence of larvae.

Most of the larvae were taken from shaded dry-wash gullies where American elm, chittamwood, and burr oak trees were present. Except in three locations, American elm was always present. A series of 12 larvae, ranging in size from very small to full grown, were collected in about 4 square yards of slightly moist grass-covered soil under a small buttonbush. Two *Hybomitra lasiophthalma* (Macq.) larvae were taken in the same place, the only instance of another species being collected in the same location with *Tabanus sulcifrons*.

Several larvae, ranging from 8 to 32 mm. in length, were collected from slightly moist grass-covered soil along a slight drainage depression traversing an open sod pasture. There were no trees or bushes within several hundred feet. Other examinations of treeless pasture land were negative, therefore this one finding seems atypical.

In one favorable site approximately 10 square yards of soil were examined and 28 larvae, ranging in length from 4 to 32 mm., were found. Thus, one collection consisted of larvae ranging in size from very small to nearly grown.

Collections were made throughout the year and, although grown larvae were most abundant in May and June, they were found every month. Most field-collected larvae, when brought to the laboratory, completed their growth and emerged within a year; however, some required more than one year to complete their development. This observation, together with field findings, suggested that *sulcifrons* may have either a 1- or a 2-year life cycle.

Apparently *Tabanus sulcifrons* larvae will feed whenever soil temperatures become warm enough for activity. A number of fully engorged larvae were collected in the last week of February 1951. Nearly all larvae collected early in March showed evidence of having fed recently and were quite active.

Three pupae of *Tabanus sulcifrons* were found in the same location in which larvae were collected. One pupa was lying in a horizontal position very near the soil surface. The other two were in a vertical position with the anterior end of the pupa nearly exposed. One of these emerged as a male on July 2, 1950, the earliest seasonal emergence of this species in the laboratory.

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[2] Report of a study made under the Research and Marketing Acts of 1946, in a cooperative project between the Bureau of Entomology and Plant Quarantine and the Experiment Station of Oklahoma A. and M. College.

[3] The author is indebted to D. E. Howell for advice and guidance, and to Alan Stone for identification of flies.

Field Tests of Insecticides against Ectoparasites of Poultry[1]

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Three ectoparasites—the chicken body louse, *Eomenacanthus stramineus* (Nitz.), the chicken mite, *Dermanyssus gallinae* (Deg.), and the fowl tick, *Argas persicus* (Oken)—are perhaps the most important species attacking poultry in the United States. The chicken body louse and the chicken mite are found wherever poultry is raised, but the fowl tick is restricted to the semiarid region of the Southwest.

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, Dec. 10–13, 1951

Table 1.—Summary of data of field tests with various chlorinated hydrocarbon insecticides against three ectoparasites of poultry.

Material	Formulation	Concentration (Per Cent)	Number of Tests	Approximate Number of Birds	Results
			Chicken Body Louse		
Methoxychlor	Dust	1.0	1	75	Poor, applied *en masse* 0.6 oz. of dust per bird
DDT	Dust	10.0	5	200	Good, applied *en masse* 0.6 oz. of dust per bird
Lindane	Slurry	3.0	1	100	Good, roost paint
		1.0	1	75	
	Emulsion	3.0	1	50	
		1.0	1	50	
		0.5	2	75	Poor, roost paint
	Mist	0.5	1	150	Poor, 250 cc. of spray applied as a mist
		0.5	4	400	Good, 500 cc. of spray applied as a mist
	Spray	0.5	6	1000	Good
Chlordane	Spray	2.0	1	500	Good, deposit of 2.5 grams of chlordane per sq. ft.
			Chicken Mite		
DDT	Dust	5.0	1	150	Very poor, 0.7 oz. of dust per nest
	Spray	10.0	1	300	Good
		5.0	1	300	
Lindane	Spray	0.5	6	800	
		0.4	1	150	
		0.25	3	475	
		0.1	1	50	Questionable
Toxaphene	Dust	5.0	1	150	Very poor, 0.7 oz. of dust per nest
	Spray	5.0	2	300	Fair
		1.0	1	150	Poor
		0.5	1	200	Very poor
Chlordane	Dust	5.0	1	150	Very poor, 0.7 oz. of dust per nest
	Spray	4.0	2	300	Fair
		2.0	2	300	Poor
		1.0	2	300	
		0.5	2	300	
Pyrethrins and piperonyl butoxide	Spray	0.1 1.0	1	500	Very poor
			Fowl Tick		
Lindane	Dust	1.0	1	1	Larvae killed in 24 hours.
	Spray	0.5	1	125	Good
		0.4	1	300	
		0.2	2	200	
		0.1	2	325	Fair
		0.05	2	250	Questionable
Toxaphene	Spray	4.0	1	25	Good
		2.0	1	150	
		1.0	2	150	
		0.5	1	50	
Chlordane	Spray	1.0	1	200	Fair
		0.5	3	350	
		0.25	1	100	
Dieldrin	Spray	0.1	2	250	
		0.05	1	225	Questionable
Aldrin	Spray	0.5	1	100	Good
		0.25	1	150	

It is difficult to determine the losses incuerrd by the poultry industry as a result of these ectoparasites, but it is reasonable to assume that the monetary loss would be great. It might be considerably greater than is suspected. Egg and meat production and the thriftiness of a poultry flock are all affected by any irritation due to the chicken body louse or any loss of blood caused by the chicken mite and the fowl tick. Lowered vitality of the birds caused by these ectoparasites often precedes outbreaks of bacterial and virus diseases.

In laboratory screening tests conducted by the Bureau of Entomology and Plant Quarantine several chlorinated hydrocarbon insecticides have shown considerable promise for controlling the fowl tick. Therefore, during the past 4 years, in the vicinity of Kerrville, Texas, the Bureau has conducted field tests to determine the effectiveness of these insecticides against other poultry parasites. The results obtained with the chicken mite, the chicken body louse, and the fowl tick are given in this paper. The number of tests with dieldrin and aldrin were limited because of the toxicological hazard involved.

METHODS AND PROCEDURE.—Most of the tests were conducted in poultry houses typical of the area. In a few of these tests the three species of ectoparasites were present in the same test. Some tests against the fowl tick were conducted in implement sheds and trees in which the poultry were permitted to roost. All of the parasite infestations developed naturally on the birds or on the premise. Approximately 5 gallons of spray was applied with a wheelbarrow-type power sprayer to the walls, roosts, and floor of each poultry house (12 by 12 by 7 feet). The sprayer was calibrated to deliver the spray at a pressure of 100 to 150 pounds per square inch. If the material was applied as a roost paint, only the roosts were treated. In most of the tests in which dust was used it was applied to the flock *en masse* with a hand rotary-type duster.

In a few exploratory tests only one or two birds were treated individually with a highly toxic material.

Mortalities of the chicken body louse were determined by examining 25 birds selected at random; for the chicken mite and the fowl tick the roosts and other hiding places were examined. Counts were usually made 24 and 48 hours after treatment and also after 1 week. Thereafter, periodic examinations were made for 4 to 6 months.

Results.—In general, against the three ectoparasites involved, lindane was considered more effective than the other materials tested. It gave good control of the lice and the mites, and was effective against the fowl tick. Lindane gave good initial kill of the fowl tick but did not possess residual qualities equal to that of chlordane or toxaphene.

Lindane at 0.5 per cent concentration failed to control the chicken body louse when applied at the rate of 250 cc. as a mist over the birds, but 500 cc. of the same material applied in the same manner gave excellent control of the lice.

A deposit of 2.5 grams of chlordane per square foot applied as a spray to the inside of the house gave good control of the chicken body louse.

A 1.0-per cent methoxychlor dust applied *en masse* with a hand rotary-type duster at the average rate of 0.6 oz. of dust per bird failed to control the chicken body louse. A 10.0-per cent DDT dust applied in the same manner and at the same rate gave good control of the lice.

The results obtained with chlordane and toxaphene against the chicken mite were disappointing, since other workers have reported good control of mites with chlordane. DDT, toxaphene, and chlordane dust containing 5 per cent of active ingredient did not give good control of mites when applied directly into the nest at the rate of 0.7 oz. of dust per nest. We offer no explanation for our failure to control the chicken mite with chlordane.

Throughout these tests no difference was noted between the effectiveness of a spray made from an emulsion concentrate and one made from a wettable powder.

Dieldrin and aldrin showed promise for the control of the fowl tick.

DISCUSSION.—The writer believes that poultry management is an important factor in the control of ectoparasites. Particularly is this true of the chicken mite and the fowl tick. Make-shift poultry houses and the tendency of many fowls to roost in trees throughout the year in the southwest make these two parasites extremely difficult to control. Complete coverage, together with adequate penetration of the hiding places, is almost an impossible and impractical task. Repeat treatments may be required for satisfactory control regardless of the concentration or the material used.

Consistently better results are obtained when the infestation is confined to a more-or-less modern poultry house. Abolishing roosts in the poultry house and maintaining poultry on a litter of straw, peanut hulls, or sawdust could influence the natural development of ectoparasites. This practice might also influence the method of treatment required for the control of these parasites. Litter treatment, as such, is not discussed in this paper. The effect of such a treatment with chlorinated hydrocarbon insecticides on fowls is unknown. However, it may be assumed that the toxicological hazard involved would be greater for litter treatment than it would be for roost-paint treatment or spraying the inside of the poultry house. Not a single fatality among the birds was reported from the materials used in these tests. However, unpublished data of a contemporary worker indicate that DDT, toxaphene, chlordane, and lindane may be highly toxic when applied directly to the fowl.

Repellency of Cotton Tufts to Flies

WILLIAM J. WALL, JR. and STANLEY F. BAILEY,
University of California, Davis

For some years it has been a practice of housewives in various parts of the country to place small dabs, balls, or tufts of white cotton on window an door screens to repel flies. In the summer of 1950 considerable publicity was given to this idea. The writers were unable to find any published reference subject, and inquiries directed to various entomologists brought to light little positive information. Therefore, a series of tests was set up in 1951 to ascertain the efficiency of this method of repelling flies.

Two window screens, each 2 feet square, were used in the first series of tests. On one screen a ball of cotton about 4 inches in diameter was fastened to the center. The other screen without cotton was employed as a check. Circles of 6 and 12 inches from the center of the cotton were marked off, and the number of flies alighting on the cotton or in the circles was counted. The flies were brushed away and another count recorded when they again alighted.

Counts were made with the screens in different positilns and exposures, and at different times of day, in a cow barn where the flies, *Musca domestica* L., were extremely abundant. The surface of the cotton ball was fluffed up in one instance and pulled tight and smooth in another. In a third test a 12-inch square of cotton placed in the center of the screen was employed. Approximately 100 counts were made in each of these tests over a period of 5 days.

In test four small tufts of cotton were staggered in the center of sixteen 6-inch squares into which the screen was divided. Separate counts were made on each square; the total number of counts being 400. Lastly, in test five a loose ball of cotton about one and one-half inches in diameter was suspended from a string on a wall surface on which a12-inch circle was marked off. The cotton, when not kept in motion by the breeze, rested in the center of the circle. A similar, adjacent circle without cotton was used as a check. The wall surface was washed before the test in order to remove all dirt and old fly specks. The flies from a nearby incinerator alighted on the test surfaces, and the specks in the two circles were counted after 6 weeks of exposure. The circles were divided into four equal quadrants, and the separate counts were averaged. This basic method was employed originally in 1935 by Freeborn & Berry.

The data obtained in the first four experiments were tested for significant repellency by the chi-square method, and that in test five by the sum of the squares method and Fisher's "t" tables.

It should be pointed out that this experiment was by no means exhaustive. Variations of our method could be carried on almost indefinitely using raw cotton, wool, and other fibers with infinite combinations of colors, sizes, textures, and shapes, stationary and moving. Our intention in presenting the results of this rather "simple" and direct method of repelling flies was to determine its practical value in the form employed by the homeowner.

During the experiments using loose cotton, it was noted that flies approaching the cotton to alight suddenly veered off. This reaction occurred so often that flies were placed in vials containing loose pieces of cotton to observe their reaction when contact with the cotton was unavoidable. When the flies walked on the cotton, the fibers soon became entangled in the spines of their legs, rendering them helpless. It would appear, therefore, that the avoiding reaction was stimulated by the loose fibers of the cotton, since this particular reaction did not occur when the cotton was tighly balled.

Our conclusions are as follows: flies (in this instance the house fly) will alight on cotton although it prefers a more solid surface on which to land. The degree to which the presence of a small ball of white cotton repels flies on window screens is not statistically significant. The distance at which the cotton is placed away from the area to be protected is unimportant. The difference in the degree of repellency of a loose ball vs a tight ball was not significant. The swinging ball of cotton did repel a statistically significant number of flies but when at rest it had little value.

Competition Between Saw-Toothed Grain Beetle and Indian-Meal Moth

DWIGHT F. BARNES and PEREZ SIMMONS,
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

Attempts by the writers to establish a mixed population of the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), and the Indian-meal moth, *Plodia interpunctella* (Hbn.), usually have resulted in the decline of the latter species. In stored raisins the saw-toothed grain beetle attains dominance during the summer following harvest, and the Indian-meal moth rarely becomes abundant during any part of the period of storage. These general observations led to experimental measurements of the competition between the two species.

Dishes provided with ground-glass contacts between dish and cover were supplied with 40 to 50 seedless raisins to serve as food for beetle adults and newly hatched moth larvae. Pillbox covers blackened with India ink were used to contain moth eggs. The cults were held at room temperature.

About 100 moth eggs less than 24 hours old were used in each of four dishes on Nov. 26, 1951. The dishes were populated with 0, 25, 31, and 50 beetles. Hatching records were made Nov. 29 and Dec. 1. Following an exposure to beetle predators of 16 to 18 days, each raisin was examined and the numbers of moth larvae that had become established were recorded.

Another test was begun on Jan. 15, 1952. Seventy moth eggs were placed in each of four dishes which contained 0, 25, 50, and 100 beetles. Counts of hatched eggs were made on Jan. 16, 17, 18, 21, and 23. The raisins were examined after 36 to 41 days. Unhatched moth eggs were counted, but attempts to record egg shells as a check against larval counts gave inaccurate results. Beetles were observed feeding on moth eggs. There was no beetle reproduction during the exposures.

Table 1 brings together the results of the two tests.

Table 1.—Survival of Indian-meal moth larvae on raisins following exposure of moth eggs to saw-toothed grain beetle adults.

Number of Beetles Used	Number of Moth Eggs		Per Cent of Larvae Established on Raisins
	Used	Hatched	
Experiment started Nov. 26, 1951			
0	100	84	43
25	100	99	42
31	100	96	50
50	100	100	10
Experiment started Jan. 15, 1952			
0	70	49	45
25	70	61	38
50	70	58	16
100	70	66	8

In the dishes provided with 0 to 31 beetles the differences in larval survival were small and somewhat irregular. There was a sharp contrast, however, between that group and dishes containing 50 or 100 beetles, in which only 8 to 16 per cent of the available eggs produced larvae that were able to

survive. The results are further evidence that a heavy infestation of the saw-toothed grain beetle can suppress an Indian-meal moth population.

A New Type of Aspirator

YUNG-CHANG CHAO and ALVAH PETERSON, *Ohio State University, Columbus*

It is a common practice in making large scale insecticidal tests to transfer lots of a test insect of a given number from a stock culture to holding or collecting containers. An ordinary aspirator may be employed; however, this type requires a transfer of the insects from the aspirator to a holding container. This act involves time and may also injure some of the insects.

The following modification in a direct suction or blower-suction (venturi type) aspiratory (Peterson, 1949, Woodbury and Barnhardt, 1939) makes it possible to collect the test insects directly into a holding container. This operation saves time and eliminates injury to specimens. The new aspirator is a T-shaped glass tube, 0.875 inch in diameter with the top of the T 6.5 inches long and the stem portion 3.5 inches high. One end (A) is provided with a rubber stopper containing a brass blower-suction

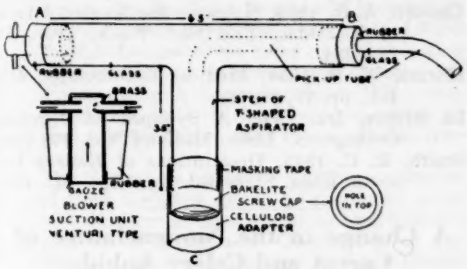

FIG. 1.—Details of aspirator.

unit of the venturi type, which is attached to an air pressure line. The opposite end (B) has a glass pick-up tube, 0.25 inch in diameter. The pick-up tube enters the aspirator through a rubber stopper and continues as a straight tube to the stem of the T-tube. Here the pick-up tube has a right angle downward bend and is cut off at a point a little below the entrance to the stem. Insects sucked through this pick-up tube will fall into a container at the bottom of the stem and will not be sucked toward the suction end (A) of the aspirator.

In this particular aspirator bakelite, screw-cap, glass vials, 1 inch by 3¼ inches, are used as holding or collecting containers. These vials are a trifle larger than the stem of the T-tube. They are fitted to the stem (C) by a celluloid, cylindrical, sleeve called an adapter. This adapter has an inner diameter the same as the outside diameter of a bakelite screw-cap. The bakelite cap, with its top removed, is sealed beneath the edge of the stem of the T-tube. Since the sleeve is larger than the stem of the aspirator, masking tape is wrapped about the glass until a tight fit results between the sleeve and the aspirator. The sleeve can be sealed to the tape with household cement or acetone. Each time a sample is collected, a new screw-cap vial is twisted into the adapter. As soon as the desired number of specimens have been picked up, the vial is removed and covered with a screw-cap. If larger holding containers are used, one may contruct suitable adapters. Such versatility makes the aspiratory widely useful.

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A Case Bearing Coleopteron, *Diachus auratus* (F.)[1]

E. A. DICKASON, *Oregon Agricultural Experiment Station, Corvallis*

At present only three subfamilies of Coleoptera are known to bear cases in the immature stages. These subfamilies, Clytrinae, Chalmydinae, and Cryptocephalinae are in the family Chrysomelidae. Recently the bronze willow flea beetle, *Diachus auratus* (F.), in the subfamily Cryptocephalinae, was reared in the laboratory and was found to have the case bearing habit. The adults have been reported as a pest at various times. Recently the species has damaged strawberries in Utah and avocados in California. The previously unknown immature stages occur on blossoms of red clover in Oregon.

Observations were made in the laboratory where the activities of the insects could be more or less controlled. Red clover heads were collected and the stems wrapped tightly with cellulose cotton and forced into shell vials filled with water. The blossoms and vials were kept in covered petri dishes to confine the larvae. This technique kept the clover heads fresh for several days and reduced the formation of molds.

Eggs were obtained in the laboratory by confining large numbers of adults in a lamp chimney with a single clover bloom. The eggs were kept loose in a covered watch glass until they hatched and then were transferred to the petri dishes. The larvae were reared singly or in groups of three per bloom.

The eggs are laid in the blooms and on the under side of the leaves of the plant. They are enclosed in a 0.5 to 0.6 mm. heavily sculptured oval case which, because of its texture, catches on the pubescence of the plant parts. In 10 to 14 days the eggs hatch and the larvae open one end of the case. The larvae drag the protective case with them at all times and when disturbed they draw into the case with the front of the head closing off the entrance. They may remain quiescent for some time before resuming activity. Feeding is done on the small florets without any apparent damage to the blooms.

In 6 to 8 days the larvae split the case longitudinally and enlarge it with small bits of floral parts and debris. They also add to the length of the case to accommodate their increased growth. This process requires approximately 24 hours to complete. By this method the case is enlarged from 0.5 mm. at incubation to 2.8–3.0 mm. at pupation. The average larval stage was 30 to 34 days, with a maximum of 42 days. The larvae close off the end of the case and then pupate for 20 to 21 days. The metallic bronze adult leaves the end of the case through a hinged door.

[1] Technical Paper No. 728 with the approval of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

Substitutes for Milkweed Seeds in the Rearing of Milkweed Bugs

HUBERT FRINGS AND LORRAINE PEISSNER,
Pennsylvania State College, State College, Penn.

The large milkweek bug, *Oncopeltus fasciatus*, has been widely used as an experimental insect in the laboratory and has proved quite satisfactory. However, there is no open market at present where milkweed seeds used for food can be purchased. Those who wish to rear the bugs must collect pods from milkweed plants and clean the seeds. Much time is consumed in this procedure, and this might discourage the use of *O. fasciatus* as a laboratory animal, in spite of its good features. An inexpensive and readily available food substitute would therefore be useful.

Lea & Niswander (1950) reported that watermelon seeds with the seed coat cracked or removed could be substituted successfully for milkweed seeds. Later Lea (1951)[1] tried other substitute foods and found sunflower or pumpkin seeds with the seed coat removed just as satisfactory. On the suggestion of Lea, we tried all of these, plus squash seeds, and reared milkweed bugs for at least five generations on each of them just as well as on milkweed seeds. All of these seeds are inexpensive and readily obtainable. Squash seeds are most convenient to use, because they are easily broken by hand or the seed coat can readily be peeled from the seeds. This, however, still takes time.

It seemed advisable to find, if possible, some food substitute which would not require treatment of seeds. Dog biscuit, milk powder and rolled oats were tried, both dry and moistened, but on none of these did the insects survive for more than ten days. A food which did prove satisfactory was blanched raw peanuts. These are shelled raw peanuts from which the seed coat has been removed by treatment with hot water.

We have reared milkweed bugs with these as the sole source of food for five generations just as well as with milkweed seeds. The peanuts can be split, if desired, to give greater surface area for feeding, but this is not necessary. There is a commercial market for prepared blanched peanuts, and thus they can be bought ready for use at almost any grocery store. Blanched raw peanuts, therefore, meet all the requirements for the substitute food—they give just as good growth and reproduction as do milkweed seeds, they are easily and cheaply obtainable, and they need no preparation.

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[1] Lea, A. O. 1951. Personal communication.

The Correct Spelling of the Generic Name of the German Cockroach

ASHLEY B. GURNEY, *Bureau of Entomology and Plant Quarantine, Agr. Res. Adm., U.S.D.A.*

It is unfortunate that the scientific name of such a common and universally known insect as the German cockroach, *Blattella germanica* (L.), should so frequently be misspelled. Entomological literature ranging from scientific to popular in character carries the spelling "*Blatella*" nearly as often as the correct form. Probably all the authors using the incorrect spelling are quite unaware of any error; in fact they may have consulted some taxonomic lists that would be assumed to be accurate. The references cited, with the exception of Caudell (1903), contain representative examples of incorrect spelling.

There is no question that this generic name requires two *t*'s, for it was so spelled when proposed by Caudell (1903), and it was correctly formed by combining the Latin diminutive suffix with "Blatta," the traditional scientific word for cockroach derived from the Latin *Blattella*, meaning the little Blatta, was proposed as a replacement for *Phyllodromia*, which was preoccupied in Diptera. Even though preoccupation was clearly established, a few authors have long persisted in using *Phyllodromia* for *germanica* and its congeners. Since the validity of *Blattella* can not be questioned, it is to be hoped that association of the name with Blatta may be a reminder of the correct spelling, with two *t*'s.

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A Change in the Nomenclature of Carrot and Celery Aphids

E. O. ESSIG, *University of California, Berkeley, Calif.*

Aphids infesting carrots, celery, poison hemlock, and related umbelliferous plants are of considerable importance in Western North America and elsewhere because they are vectors of plant virus diseases of these hosts. In this area two species of aphids are of special importance and the latest nomenclature of these is as follows:

The names of the carrot aphid and the celery aphid, formerly designated as *Aphis* or *Anuraphis ferruginea-striata* Essig, have been changed to the following:

The carrot aphid, *Sappaphis foeniculus* (Theobald) (*Anuraphis*), and the celery or poison-hemlock aphid, *Sappaphis apiifolia* (Theobald) (*Anuraphis*).

According to European aphidologists, the names of other common species now placed in the genus *Sappaphis* Matsumura, are *Aphis sorbi* Kalt., and *Aphis mali* (Ferrari) [*Anuraphis roseus* (Baker)] and other species.

In the genus *Yezabura* Matsumura is the important *Aphis tulipae* (B.d.F.) and other species.

In the genus *Brachycaudus* v. d. Goot are *Aphis cardui* L., *Aphis persicaecola* (Bdv.) [*Aphis persicae-niger* (Smith)]; *A. helichrysi* (Kalt.) (*Aphis* and *Anuraphis*) and others.

A recent and comprehensive revision of the aphids of central Europe entitled: "Europae centralis Aphides die Blattläuse Mitteleuropas by Kurt Branco, Weimer, D.D.R., has recently been published (1951) by C. BÖRNER, Naumburg, D.D.R.

PROCEEDINGS OF SEVENTH ANNUAL MEETING

NORTH CENTRAL STATES BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS MARCH 27–28, 1952, ST. PAUL, MINN.

FIRST BUSINESS SESSION MARCH 27, 1952

The Seventh Annual Meeting of the North Central States Branch A.A.E.E. was called to order by President R. C. Smith at 11:00 A.M.

President Smith called for an expression of appreciation from the 296 persons in attendance for the excellent service rendered by the Program Committee, composed of J. H. Bigger, Chmn., T. H. Parks and T. A. Brindley, the Local Arrangements Committee composed of C. E. Mickel, Chmn., F. G. Holdaway and A. W. Buzicky and the Branch Recorder R. T. Everly.

President Smith asked the Secretary to report on the actions taken by the Executive Committee during a meeting held on March 26.

1. The Committee recommends that the post-meeting price of the 1952 Proceedings and future registration fees and Proceedings charges be raised from the present rate of $2.00 to $2.50 because of the rising costs of operating the Branch and publishing the Proceedings. President Smith deferred action on this recommendation until the final business session to give members ample time to evaluate the proposal.
2. The Committee felt that a standing committee of three members should be appointed to revise the Branch Constitution so that it would conform with the new Constitution of the Parent Association. The new President elected for the 1952–53 year should make the selection of this committee. This proposal was approved unanimously by the membership.
3. The Committee suggests that the proposed Constitution Revision Committee consider placing a five-year limitation on the successive years that a Secretary-Treasurer can serve in office. Since there was no dissension to this proposal, President Smith stated that it would be referred to the Constitution Committee after its formation.

President Smith appointed the following committees:

Resolutions Committee
W. E. McCAULEY, *Chmn.*
H. O. DEAY
D. A. WILBUR
W. M. ROGOFF

Auditing Committee
R. L. POST, *Chmn.*
R. L. JANES

Time and Place of 1952 Meeting Committee
R. B. NEISWANDER, *Chmn.*
L. HASEMAN
H. M. HARRIS

R. T. Everly was appointed as Recorder to prepare the 1952 *Proceedings*. President Smith called for a report from the Nominating Committee.

T. C. Allen speaking for the Nominating Committee presented the following state of officers for the coming year:

For *President:* T. H. PARKS and E. HIXSON
For *Vice-President:* P. A. DAHM and D. W. HAMILTON
For *Secretary-Treasurer:* J. W. APPLE and H. A. GUNDERSON

President Smith called for additional nominations from the floor but when none were forthcoming the nominations were declared closed. The members were instructed to mark their ballots and place in the ballot box before 5:00 P.M. on March 27.

President Smith called for nominations for the new Nominating Committee. Before the nominations were closed, the following persons were nominated.

C. J. WEINMAN	P. A. DAHM
R. A. DAVIDSON	J. T. MEDLER
A. W. BUZICKY	R. L. JANES

The members were instructed to vote for three members to serve on the Nominating Committee. The Chairman of this Committee would be the persons receiving the greatest number of votes.

Vice-President J. H. Lilly was given the chairmanship of the meeting and he introduced President R. C. Smith who delivered a most inspiring Presidential Address.

President Smith called on E. F. Knipling as President of the *American Association of Economic Entomologists* for a word of greeting.

Dr. Knipling expressed his appreciation for being able to attend the annual meeting of the North Central States Branch. He reviewed some of the activities of the parent association and discussed at some length the possible changes in the organization if the American Association and Entomological Society consolidate.

Dr. Knipling stressed the importance of Branch meetings as outlets for much of the entomological work in the country. He complimented the North Central States Branch on its program arrangement whereby the more important economic problems are given special emphasis.

Meeting adjourned by President Smith.

SMORGASBORD
THURSDAY, MARCH 27, 1952, 6:30 P.M.

McLaughlin Gormley King Company of Minneapolis played host to those attending the Branch meeting at a most enjoyable Smorgasbord in celebration of the 50th Anniversary of the Company.

FINAL BUSINESS SESSION MARCH 28, 1952

The meeting was called to order by President Smith at 11:30 A.M. President Smith called for the following reports:

TREASURER'S REPORT
MARCH 21, 1951 TO MARCH 26, 1952

Credits

Balance in Treasury—March 20, 1951	$ 494.47	
Sale of 382 Proceedings @ $2.00 ea.	764.00	
Postage payment for mailing one Proceedings to Russia	.39	
Surplus during 1951 registration	9.00	
Bank interest	6.28	
	$1,274.14	$1,274.14

Debits

Expenses for 1951 meeting	$ 45.29	
Expenses of Secy.-Treas. at 1951 meeting	36.66	
Expenses of Recorder at 1951 meeting	18.49	
Paid to Democrat Printing Co. for 1951 programs	84.00	
Paid to J. J. Kulk for 1951 badges	24.85	
Paid to Democrat Printing Co. for 1952 programs	75.25	
Paid to Democrat Printing Co. for 1952 badges	10.25	
Paid to Letter Shop for four mailings to membership	142.68	
Cost of preparing 1951 Proceedings	707.20	
Paid to Norma Itten for secretarial help	15.00	
Paid to U. S. Post Office for stamps	4.00	
Paid to First National Bank for two extra withdrawals	.50	
Paid to Rowley & Schlimgen for receipt book	2.00	
	$1,166.17	$1,166.17
Balance on hand March 26, 1952		$ 107.97

Submitted by J. W. APPLE, *Secretary-Treasurer*

REPORT OF AUDITING COMMITTEE
MARCH 27, 1952

The books have been audited and found in good order and correct.

Auditing Committee
R. L. POST, *Chairman*
RAY L. JANES

The reports by the Treasurer and Auditing Committee were accepted by the membership.

REPORT OF RESOLUTIONS COMMITTEE

Resolution No. 1

WHEREAS, This the seventh annual meeting of the North Central States Branch of the American Association of Economic Entomologists has been successful, enjoyable and pleasant due in large measure to the careful planning of the Program Committee and to the work of the Local Arrangements Committee, therefore

Be it resolved, That an expression of gratitude and appreciation be extended the members of these two committees and

Be it further resolved, That an expression of appreciation be extended to the officers of the Association with particular note of indebtedness to our President for his preparation and delivery of an inspiring address.

Resolution accepted unanimously.

Resolution No. 2

WHEREAS, The McLaughlin, Gormley, King Company of Minneapolis in celebration of its 50th anniversary as manufacturers of insecticides, invited the members of the North Central States Branch of AAEE to be its guests at a delightful smorgasbord at the Hotel Lowrey, and

WHEREAS, The smorgasbord was enjoyed by all, therefore

Be it resolved, That the membership of the North Central States Branch express its appreciation to the McLaughlin, Gormley, King Company for its generous hospitality and that best wishes be extended to the Company on the occasion of 50 years of outstanding service to American industry and agriculture and

Be it further resolved, That the Secretary be instructed to forward copies of this resolution to the officials of the Company.

Resolution accepted unanimously.

Resolution No. 3

WHEREAS, The use of visual aids greatly enhances the presentation of informational material and

WHEREAS, The imposition of charges upon the speaker for the use of such visual aid equipment tends to discourage the use of such equipment, therefore

Be it resolved, That the North Central States Branch assume the expenses of securing and using standard slide projectors and 16 mm. sound movie equipment to be used in connection with its annual meeting.

Resolution accepted by majority.

Resolution No. 4

WHEREAS, The Program Committee during the preparation for this the seventh annual meeting found it necessary to eliminate a number of subjects submitted for discussion and the members were therefore deprived of the opportunity of hearing discussion on these subjects and

WHEREAS, To include the number of topics which do appear on the program it was found necessary to arrange three concurrent sessions for three one-half day periods in addition to one evening session and

WHEREAS, The membership must travel considerable distances at much expense, therefore

Be it resolved, That the North Central States Branch extend its period of meeting from 2 days to 3 days.

This resolution was not accepted by the membership.

Resolution No. 5

WHEREAS, Legislation concerning insect control and regulation of pesticides is of vital interest to many entomologists and

WHEREAS, Most entomologists do not have the time nor the facilities to learn of proposed legislation that deals with insect control and

WHEREAS, Such information on proposed legislation if available to entomologists could be useful to them and would encourage them to participate more actively in the operation of our democratic processes, therefore

Be it resolved, That the North Central States Branch of the American Association of Economic Entomologists request the parent organization to appoint a standing committee whose duties will be the assembling, evaluation, and distribution of information concerning proposed legislation on matters pertaining to insect control, pesticides, and any other legislative matters of vital interest to the membership.

Resolution accepted by majority.

Resolution No. 6

WHEREAS, The discussions presented at the meetings of the North Central States Branch AAEE generally present the latest information on the life history, habits, and control of the injurious insects in our area and

WHEREAS, This information is of foremost value to entomologists of the area in formulating plans and recommendations for the current season and

WHEREAS, The meetings are held rather late in the winter so that by the time the Proceedings are published and distributed to the members, they are too late to be of much value during the current season, therefore

Be it resolved, That the Executive Committee of the North Central States Branch AAEE explore the possibilities of having abstracts of talks submitted in advance so that they may be assembled for distribution to the membership at the time of registration.

Resolution accepted unanimously.

Resolution No. 7

WHEREAS, The Food and Drug Administration Tolerance Hearings on use of many pesticides in food crops have been terminated for approximately 18 months and

WHEREAS, That Administration has not yet announced tolerances or tentative tolerances for the pesticides covered by extensive testimony during the aforementioned hearings and

WHEREAS, The absence of such tolerances continues to result in and contribute to confusion, waste, and loss due to less efficient control of many important pests and

WHEREAS, The absence of such tolerances makes it impractical for the officials of the Insecticide Division of PMA in the U. S. Department of Agriculture to register labels for many pesticides covered in testimony presented in the aforementioned hearings and

WHEREAS, Each commercial organization presented briefs covering its products thereby simplifying the task of reaching recommendations for tentative tolerances, therefore

Be it resolved, That the North Central States Branch AAEE urgently request the prompt announcement of tolerances for the pesticides covered by testimony during the aforementioned hearings and

Be it further resolved, That the Secretary of the North Central States Branch be instructed to forward this resolution to the Commissioner of the Food and Drug Administration and to the Chief of the Federal Security Administration, Washington, D. C.

Resolution accepted by majority.

Resolution No. 8

WHEREAS, The Study Group appointed by Secretary of Agriculture, Charles F. Brannan, to review and evaluate the Insect and Plant Disease Programs of the B.E. & P.Q. has in its Report recommended expansion of entomological research and increased educational efforts related to insects and plant diseases and

WHEREAS, Such recommendations should markedly increase the effectiveness of insect control and promote interest in the profession of entomology, therefore

Be it resolved, That the North Central States Branch AAEE express its concurrence in the recommendation set forth in the Report of the aforementioned Study Group and commend the Study Group for its conclusions and proposals and

Be it further resolved, That the Secretary of the North Central States Branch forward copies of this resolution to Secretary of Agriculture, Charles F. Brannan, and to each member of the committee which carried out this assignment.

Resolution accepted unanimously.

Submitted by the Resolutions Committee
W. E. MCCAULEY, *Chairman*
D. A. WILBUR
W. M. ROGOFF
H. O. DEAY

REPORT OF TIME AND PLACE COMMITTEE

The Time and Place Committee consisting of H. M. Harris, Leonard Haseman and R. B. Neiswander report that after careful consideration of all of the invitations received, they recommend that the next annual meeting of the North Central States Branch of the American Association of Economic Entomologists be held on March 26 and 27, 1953 at St. Louis, Missouri.

R. B. NEISWANDER

President Smith opened the discussion on the proposed increase in registration fee charge for the Proceedings or both. It was moved and seconded that the recommendation of the Executive Committee be accepted.

J. J. DAVIS—I would like to amend the motion to make the charges $3.00 instead of $2.50.

President called for a vote on the Davis amendment to the motion. This was defeated. *A vote on the original motion indicated a majority approval.*

The Secretary was called on to read a letter from Ray Hutson in which the Branch was invited to East Lansing, Michigan in 1955. President Smith referred action on this offer to the new Executive Committee.

President Smith called on T. C. Allen to give the results of the elections.

Nominating Committee
C. J. WEINMAN, *Chmn.*
A. W. BUZICKY
P. A. DAHM

Secretary-Treasurer	J. W. APPLE
Vice-President	P. A. DAHM
President	T. H. PARKS

President Smith called the newly elected officers to the rostrum and transferred the direction of the Branch to President-elect Parks.

President-elect Parks accepted the chairmanship of the Branch and called on the members to give him the necessary cooperation in the conduct of Branch activities. He stated that the new Constitution Revision Committee would be appointed by mail.

Meeting adjourned by President Parks.

MINUTES OF THE SIXTEENTH ANNUAL SPRING MEETING

GEORGIA ENTOMOLOGICAL SOCIETY

Savannah Hotel, Savannah, Ga. March 7–8, 1952

The meeting was called to order at 1:30 P.M. on March 7. President W. G. Bruce introduced Mr. Hadley Cammack, vice-president of the Savannah Chamber of Commerce, who welcomed the group to Savannah. President Bruce responded to Mr. Cammack's welcome and spoke briefly on "The Entomologist and the National Defense Effort." He pointed out some of the many ways in which the work of the entomologist was essential in the defense effort and urged full support of this work by the public and by the various governmental agencies, National, State, and Local.

Dr. E. F. Knipling, President of the American Association of Economic Entomologists, commented briefly, endorsing heartily the idea of State entomological societies. He discussed briefly the question of the consolidation of the two national entomological societies and urged attendance at the coming meetings at Philadelphia.

Mr. W. W. Rowe, Jr., of the Ashcraft Wilkinson Co. of Atlanta, speaking for the National Agricultural Chemicals Assoc., predicted that if full use of alternate chemicals is made, insecticide supplies will probably be adequate for 1952. Lead arsenate, sulfur, and copper compounds are short, as are containers. He strongly urged early buying of chemicals to offset possible inequities in distribution and shortages in particular insecticides.

President Bruce then called for the report of the Secretary-Treasurer, which read as follows:

As of March 5, 1952, the Georgia Entomological Society has an active membership of 90.

As directed by the Society, messages of thanks were sent to Lt. Tom Gunn, USNR, for his telegram of felicitation and to Dr. P. M. Gilmer, USBEPQ, Washington, D. C.; to Pres. G. P. Donaldson, Abraham Baldwin College, Tifton, Ga.; and to Mr. F. E. Allison, Calif. Spray Chemical Corp., for their part in the success of the Tifton meeting. Newspaper notices of the meeting at Tifton were sent to the papers in Athens, Atlanta, Fort Valley, Macon, Tifton, and Savannah.

Over 100 copies of the minutes of the Tifton meeting were sent to interested entomologists and a rather full statement of the proceedings was sent to Secretary E. N. Cory of the American Assoc. of Economic Entomologists for publication in the Journal. A copy of a letter from Dr. Cory to Dr. Peairs (editor of the Journal) dated February 29 is at hand in which Dr. Cory recommends that hereafter the minutes, including paragraphic abstracts of papers presented, be published in the Journal also.

Letters were sent to 17 industrial organizations in Georgia inviting them to send representatives to this meeting and to join the Georgia Entomological Society. Similar invitations were went to eleven out-of State organizations and entomologists, The final point of instruction to the Secretary was taken care of by the program committee when it prevailed upon three distinguished out-of-State entomologists to present papers at this meeting.

Society envelopes and letterheads were printed also according to instructions.

The state of the treasury is as follows:

Credits

On hand at date of last report (March 9, 1951)	$ 93.58
Dues paid	56.00
TOTAL CREDITS	149.58

Debits

Stationery and mimeograph stencils	11.61
Stamps and postcards	12.57
Express	1.08
TOTAL DEBITS	28.26
Cash on hand in National Bank of Athens	121.23
Petty cash fund	.09
TOTAL CASH ON HAND	$121.32

Respectfully submitted,
(Signed) HORACE O. LUND
Secretary-Treasurer

President Bruce appointed the following committees:

Auditing: C. M. BECKHAM, O. K. FLETCHER, H. N. POLLARD

Resolutions: O. I. SNAPP, W. E. BLASINGAME, THOMAS DUCK

Nominating: M. R. OSBURN, J. C. ALDEN, C. C. FANCHER

O. I. Snapp, Chairman of the Publications Committee, who represented the Society at the September meeting of the Florida Entomological Society, stated that the Florida Society was not interested in altering its present arrangements for the "Florida Entomologist" in such a way as to make it a joint publication of the Georgia and Florida Societies. He recommended membership in the Florida Society for those who would publish in the "Florida Entomologist."

Mr. G. G. Rohwer, Chairman of a Constitutional Revision Committee, discussed certain proposed changes in the Constitution and suggested that the secretary initiate the proper procedures to accomplish the revisions. A motion to this effect by Mr. Snapp was adopted.

President Bruce then recognized Mr. Homer Harris, a new member of the Society, for his part in the heroic rescue of a Negro child from a burning home.

The first paper-reading session followed:

1. E. F. Knipling, BEPQ, Washington, D. C., spoke on "The Present Status of the Screw-worm Problem and New Developments." He stated that it was now proposed to eliminate the screw-worm from the Southeast by liberation each week for several weeks of about 10,000,000 flies previously sterilized by x-rays. Pilot experiments on Santa Belle Island off the Florida coast indicate the feasibility of the program.

2. Roy Fritz, USPHS, Atlanta, discussed "Disaster Insect Control Operations" in which he related

the part played by the USPHS in the Columbia River Flood of 1948 and the Kansas City Flood of 1951 in the control of pest mosquitoes.

3. R. W. Fay, USPHS, Savannah, discussed some of the problems involved in the development of "Radioactive Isotopes in Tagging Insects," such as the selection of an isotope that will be detectable but not too toxic either to the insect or to man, that will mark both sexes of insects, and that will persist long enough for the purposes of the experiment.

4. A. D. Hess, USPHS, Savannah, then reviewed the "Entomological Work of the Technical Development Branch of the CDC" at its various stations distributed over the United States and its possessions.

5. Max R. Osburn, BEPQ, Albany, discussed his "Experiments for Pecan Weevil Control in 1951." Under conditions of light infestation, he found 6 pounds of 50% wettable DDT or 6 pounds of 40% wettable toxaphene to 100 gallons of water gave perfect control. Where weevil infestations were very heavy, control was not as good. Two pounds of 25% parathion reduced a heavy infestation but was not satisfactory. Damaging infestations of the black pecan aphid and the mite, *Tetranychus hisoriae* (McGregor), resulting in premature defoliation, followed the use of DDT and there was some evidence that the repeated use of DDT caused a reduction in nut yields.

6. O. I. Snapp, BEPQ, Fort Valley, found in his "Peach Insect Investigations in 1951" that in both small and large plot experiments dieldrin in four applications placed first and parathion in five applications placed second against the plum curculio. Perfect control was obtained in lightly infested large-scale plots with dieldrin. Parathion, EPN, and aldrin were effective and methoxychlor and lead arsenate gave fairly good results. Under an unprecedented infestation, the percentages of curculio-infested peaches at harvest ranged from 45.6 to 77.7 for all the other treatments in one-tree plots, as compared with only 7.4 where dieldrin had been used.

The flavor of fresh ripe peaches was not affected by any of the insecticides, and no injury to the fruit, leaves, buds, budwood or any part of peach trees could be discerned from any of the materials except lead arsenate, which caused the usual amount of foliage injury and injured some of the fruit.

7. H. N. Pollard, BEPQ, Fort Valley, reported on the "Life Histories and Habits of Phony Peach Disease Vectors." He pointed out that one of the principal difficulties encountered in controlling these leafhoppers stems from the wide variety of plants upon which they will feed.

8. T. D. Persons, BEPQ, Macon, spoke on "Promising New Approaches to Control of Phony Disease of the Peach." The recent adaptation of a chemical method for diagnosing phony infection in symptomless wild plums has led to the recommendation that wild plums growing near orchards should be killed with chemicals which kill the entire plant. The development of a spray program for the control of presently known vectors is also under way. These controls as adjuncts to the roguing of infected trees offer renewed hope for more efficient control of this disease which has caused the loss of more than three million peach trees in the Southeast. Combined host and vector surveys begun in 1951 may make it possible to delimit or forecast the distribution of the disease and thus improve the efficiency of control.

The session closed with a presentation of the BEPQ film "The European Corn Borer" arranged for by W. F. Turner, BEPQ, Fort Valley.

9. The annual banquet was held at 7.30 P.M. in the Camellia Room of the Savannah Hotel. President Bruce introduced the distinguished visitors and the thirty new members. Dr. A. D. Hess, USPHS, Savannah, took us on a very entertaining and educative trip, verbally and pictorially, through the Islands of the Caribbean Sea and South and Central America.

The Saturday morning paper-reading session proceeded as follows:

10. M. D. Farrar, Clemson College, S. C., discussed "Soil Insecticides." He listed the advantages and disadvantages of nine different insecticides, the effective concentrations against various insects and the phytotoxic concentrations. He indicated some recent advances in methods of application such as granulated formulations applied from airplanes. He pointed out that when root pests are eliminated, corn yields increase sometimes as much as 30 per cent and peanut yields two to three times.

11. Norman Allen, BEPQ, Florence, S. C., described "Experiments for the Control of Green June Beetle Larvae in Tobacco Plant Beds." He stated that parathion as a drench, dust, or bait was very good, as were dilan and lindane. He recommended ½ pound of 15% parathion per 50 gallons of water applied at one gallon per squareyard.

At this time President Bruce recognized Mr. Jackson, retired general agricultural agent of the Central of Georgia Railroad, and Dr. Alexandrini, visiting entomologist from Rome, Italy.

12. L. W. Morgan, Coastal Plain Experiment Station, Tifton, spoke of "Insecticides Used for Control of Tobacco Insects." He stated that an effort was being made to encourage growers to establish a regular program of applications of insecticides to minimize damage by the less conspicuous species and forms.

13. H. O. Lund, University of Georgia, Athens, told of "Some Forest Insect Problems" prevalent in Georgia in the last few years. He suggested a BHC solution in oil (0.5% gamma) be applied to the trunks of pines recently infested with the black turpentine beetle and that plenty of water be supplied to the trees. Against the Old House Borer, and powderpost beetles, he recommended the liberal application of orthodichlorobenzene, paradichlorobenzene in kerosene, or 5% pentachlorphenol in fuel oil to infested timbers.

14. J. W. Miller, University of Georgia, Athens, described "The Biology of the Square-necked Grain Beetle," *Cathartus quadricollis* Guer., which was reared under controlled conditions of moisture, light, and temperature. The various life cycle stages and the special techniques in handling each stage were described. An average of 33 days was required for completion of the life cycle from egg to adult at 30° C., 90 per cent relative humidity and total darkness.

15. D. W. LaHue, BEPQ, Tifton, told of "Progress in the Control of Stored Grain Pests." He stated that the best corn fumigant was the 4:1 mixture of carbon tetrachloride and carbon disulfide. Dusts of pyrethrum and a synergist are effective only if the infestation is light when it is applied. He described the weevil control demonstration being put on in South Georgia in conjunction with the experiment station and extension service.

16. C. H. Alden, State Department of Entomology, Atlanta, discussed "Tomato Transplant Certification." He stated that Georgia has nearly all the

certified tomato transplant business, producing approximately 700 million plants per year. He described the methods of checking on the seed, the land, the plants, and the spraying program and listed the diseases and insects most often found.

17. F. R. Blackwell, BEPQ, Tifton, spoke on "Recent Developments in the Sweet Potato Weevil Situation in Georgia." He stated that of the total number of properties found infested since 1945 (1053 in 28 counties), only 184 in 16 counties remain actively infested. Since one of the greatest problems arises from the promiscuous planting of small home patches of sweet potatoes, an active general education program must be carried to all the people. In the past six months, 16,961 inspections have revealed 159 infested properties.

18. C. M. Beckham, Georgia Experiment Station, Experiment, presented his "Recent Investigations on the Vegetable Weevil" conducted from 1948–51. He discussed distribution, host plants, habits, and seasonal occurrence and reported the first United States record of a vegetable weevil parasite, a larvaevorid, *Hyalomyodes triangulifera* (Loew). The comparative effectiveness of a number of insecticides was presented.

19. G. R. Swank, BEPQ, Fort Valley, spoke on "The Effects of Subsequent Yield Produced by Growing Tomato Transplants in DDT-Treated Soil." At pulling time the transplants were smaller and consequently the average tomato was smaller when the transplant beds were treated with 25 or 50 pounds of DDT per acre than when they were untreated or treated with only 10 pounds per acre. Total yields were the same for all treatments within each of the six varieties tested.

20. C. C. Fancher, BEPQ, Macon, discussed "Recent Modifications in the Control of the White-Fringed Beetle." He pointed out that the vegetable and flower gardener may now protect his plants with a fertilizer containing DDT. The nurseryman, the dealer in industrial supplies, and any other individual handling regulated articles may now apply a surface application of 25 pounds of DDT in 200 gallons of water per acre to his property or storage area and reduce populations for three or more years. The use of such treatments reduces the responsibility of the State-Federal project.

21. W. F. Turner, BEPQ, then presented the moving picture, "Your Enemy, The Grasshopper."

In the final business meeting, the report of the auditing committee endorsing the report of the treasurer was, on motion, accepted, as was the report of the resolutions committee, which follows:

Whereas the Georgia Entomological Society has enjoyed a most profitable and interesting meeting at Savannah, Georgia, on March 7 and 8, 1952, with the largest attendance in its history:

Be it resolved that we express our thanks and appreciation to Mr. Hamilton Laudani and Dr. A. D. Hess for making the necessary local arrangements and to Mrs. Hamilton Laudani and Mrs. H. T. Vanderford for arranging and conducting the tour of azalea-filled historic Savannah for the score of wives who attended; to Mr. W. F. Turner and Mr. G. G. Rohwer for preparing the excellent program; and to Mrs. Hamilton Laudani and Mrs. H. O. Lund, who so ably assisted with the registration.

Be it further resolved that we express our thanks to the United States Health Service CDC in Savannah for providing the necessary projectors and to the Savannah Hotel for providing the excellent meeting facilities.

Be it further resolved that the Georgia Entomological Society express its regret to Professor P. W. Fattig of Emory University for his inability to attend this meeting, the first he has missed since the formation of the Society in 1937.

Be it further resolved that we express appreciation for the presence, interest, and participation in our program of distinguished out-of-State entomologists, Dr. M. D. Farrar of Clemson, S. C., Mr. Norman Allen of Florence, S. C., and Dr. E. F. Knipling, President of the American Association of Economic Entomologists.

The report was on motion approved.

The nominating committee then recommended the election of the following slate of officers:

President: W. F. Turner, BEPQ, Fort Valley.
Vice-President: W. E. Blasingame, State Dept. of Entomology, Atlanta.
Secretary-Treasurer: H. O. Lund, University of Georgia, Athens.
Historian: P. W. Fattig, Emory University.

The secretary was instructed on motion approved to cast a unanimous ballot for these candidates.

President Bruce thanked the Society for having afforded him the honor of the presidency and presented the gavel to President-elect Turner, who then suggested that all those interested assemble at 1.30 P.M. for the tours of the Savannah laboratories of the USBEPQ and the USPHS Communicable Disease Center. Twenty persons signified their intention of going on the tour.

Members and guests registered at the sixteenth annual spring meeting were as follows:

C. H. Alden
John C. Alden
Norman Allen
F. E. Allison
E. R. Basinski
C. M. Beckham
F. R. Blackwell
W. E. Blasingame
E. P. Boland
J. E. Brogdon
W. G. Bruce
G. C. Bryant
D. P. Childs
P. H. Clark
W. H. Cross
G. W. R. Davidson
D. F. Davis
T. Duck, Jr.
M. Dupree
W. J. Dunn
C. C. Fancher
M. D. Farrar
R. W. Fay
O. K. Fletcher
W. M. Fortson
R. F. Fritz
C. C. Green
H. W. Harris
J. O. Harrison
H. B. Hayes
A. D. Hess
J. P. Hollon
C. R. Jordan
E. F. Knipling
D. W. LaHue
H. Laudani
H. O. Lund
I. E. McCall
M. McGee
J. M. Miller
L. W. Morgan
L. H. Moore
J. H. Neal
W. C. Nettles
M. R. Osburn
K. R. Parkinson
W. J. Patterson
T. D. Persons
H. N. Pollard
H. D. Purswell
G. G. Rohwer
W. M. Rowe
O. I. Snapp
M. E. Snodgrass
G. R. Swank
W. E. Towson
J. A. Turner
W. F. Turner
H. T. Vanderford
W. W. Wells
O. W. Whitehead
A. Williams
R. A. Williams
M. L. Wright, Jr.
N. W. Youngblood

Respectfully submitted,
HORACE O. LUND
Secretary-Treasurer

PROCEEDINGS OF THE SECOND ANNUAL MEETING SOUTHWESTERN BRANCH

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
San Antonio, Texas, Feb. 28–29, 1952

The Second Annual Meeting of the Southwestern Branch of the American Association of Economic Entomologists was held in San Antonio, Texas, February 28–29, 1952.

Preceding the official meeting (Feb. 27) a tour of the Kerrville, Texas, Laboratory of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, was made. Demonstrations were made by the personnel of the Laboratory.

The meeting was called to order by Chairman R. C. Bushland. Following the invocation, Vice-Chairman O. J. Chapman assumed the chair and presented Dr. R. C. Bushland for the annual address of the Chairman. The title of the address was "Co-operation in Entomological Research."

The 264 members and guests were pleased to hear greetings and comments from E. F. Knipling, our National President. Thirty-nine papers and talks were presented.

Chairman Bushland called for the following reports:

TREASURER'S REPORT

	Credits	*Debits*
Balance on hand 3-5-51	$378.17	$
Registration Receipts 3-6-51	229.00	
A.A.E.E. Refund	88.42	
Envelopes		10.65
A.A.E.E. Error Refund		88.42
Badges		31.88
Stamps		8.94
Announcements and Registration Form		8.75
Postal Card Announcements		9.37
	$695.59	$158.01
Balance on hand in Treasury		537.58
	$695.59	$695.59

SHERMAN W. CLARK
Secretary-Treasurer

REPORT OF THE AUDITING COMMITTEE

We have examined the records and books of the Secretary-Treasurer and find them in order.

J. C. GAINES, *Chairman*
J. A. CASON
H. V. CLABORN

REPORT OF THE COMMITTEE AS A WHOLE ON THE 1953 MEETING

The Secretary presented telegrams, letters, and brochures, from various cities of the State of Texas asking for the 1953 convention. H. G. Johnston presented the report of the Executive Committee recommending Galveston. Chairman Bushland called or nominations from the floor. After some discussion it was voted to hold the 1953 meeting in Galveston, Texas.

REPORT OF THE NOMINATING COMMITTEE

The Nominating Committee nominated officers for 1952–53 as follows:

Chairman, P. J. RENO
Vice-Chairman, CLYDE A. BOWER
Secretary-Treasurer, SHERMAN W. CLARK
Executive Committee, ALLEN GUNTER

STIRLING KYD, *Chairman*
DOUG EARLY
W. C. MAXWELL

The membership unanimously approved the nominations.

REPORT OF THE COMMITTEE ON RESOLUTIONS

The following resolutions were adopted by the membership:

Resolution 1

WHEREAS, the members of the Southwestern Branch of the American Association of Economic Entomologists in attendance at the Second Annual Meeting at San Antonio, Texas, on February 28 and 29, 1952, have enjoyed an interesting and profitable meeting:

THEREFORE, be it resolved that we hereby express our special thanks and appreciation to the following:

a. E. F. Knipling, President, American Association of Economic Entomologists, for his presence and interesting address.
b. F. C. Bishopp and Kelvin Doward of the Bureau of Entomology and Plant Quarantine, Washington, D. C. for their participation on the program and valuable contributions to the meeting.
c. L. F. Curl, Chairman, W. L. Barrett, and T. R. McGregor of the Local Arrangements Committee for their hard and faithful work in providing entertainment, transportation, and otherwise making the meeting a success.
d. The personnel of the Kerrville BEPQ for the very interesting, instructive, and informative program and the enjoyable barbecue lunch provided at Kerrville on February 27 for the 150 visitors.
e. Plaza Hotel for providing the excellent meeting rooms and other facilities.
f. R. C. Bushland, Chairman, A. J. Chapman, Vice-Chairman, and Sherman W. Clark, Secretary-Treasurer, for so ably fulfilling their duties during the meeting and in making preparation therefor.
g. F. A. Fenton, Chairman, and other members of the Program Committee for arranging and preparing the program.

Resolution 2

WHEREAS, the spread of the pink bollworm has increased to such alarming proportions during the

past two years, and, whereas, it is believed that the continued spread of this insect creates a threat to the most profitable production of cotton;

THEREFORE, be it resolved that this organization go on record as favoring the appropriation or the securing of sufficient funds by Federal, state, and private industry to adequately support all phases of pink bollworm research and control. It is the definite recommendation of this group that such increased appropriations should not be made available at the expense of the current cotton insect research program. And, be it further resolved, that a copy of this resolution be sent to the Secretary of Agriculture, to the Chief of the Bureau of Entomology and Plant Quarantine, to the National Cotton Council, and to the U. S. Senators and Congressmen from the Southwestern states.

K. P. EWING, *Chairman*
MANNING A. PRICE
JIM O'NEAL

The resolutions were unanimously adopted by the members.

MEMBERS AND GUESTS REGISTERED

Acock, Robert H.
Adams, J. F.
Akin, Bill
Alden, John C.
Alex, A. H.
Alsobrook, B. L.

Babb, Crawford D.
Bacon, R. L.
Baker, Harold J.
Balzer, August
Barber, C. L.
Barrett, William L.
Barton, Larry L.
Beavers, A. B.
Beckman, Herman F.
Becnel, I. J.
Behse, O. C.
Beidler, E. J.
Berry, N. O.
Bickerton, J. M.
Bieberdorf, G. A.
Bilsing, S. W.
Bishopp, F. C.
Bixby, A. F.
Bogaard, Tom
Bourland, Don T.
Bower, Clyde A.
Boyd, Bob
Bradburn, R. L.
Bramblett, W. J.
Brazeal, C. B.
Brook, Ted S.
Brooks, Fred N.
Browne, E. F.
Brownlee, John R.
Brundrett, H. M.
Brunn, Lynn K.
Buchanan, E. L.
Burg, Simon J.
Burnside, W. H.
Bushland, R. C.
Bussart, J. Everett
Butler, Hardie

Calhoun, S. L.
Carr, John B.
Carson, Nathan B.
Casey, Carl H.
Cason, J. A.
Cavitt, Hugh S.
Chada, Harvey L.
Chadbourne, Dan S.
Chapman, A. J.
Chapman, Charlie
Chase, John S.
Cherry, W. F.
Claborn, Houston V.
Clark, J. C.
Clark, Sherman W.
Condron, Carl H.
Cook, F. E.
Cook, S. E.
Cooper, Bromley F.
Cowart, L. E.
Cron, M. H.
Curl, L. F.
Curran, Robert

Dahms, R. G.
David, Roy S.
Davis, George T., Jr.
Deer, James A.
Deputy, O. D.
Diaz, Joe
Dietz, Harry F.
Dilworth, Hal C.
Dobbin, Ed
Dorward, Kelvin
D. Riss, John M.
Dubuisson, E. B.
Duval, R. C.

Earley, Doug
Echols, H. A.
Ewing, K. P.

Feistner, W. E.
Fenton, Fred A.
Fletcher, Fred
Foster, J. W., Jr.
Fox, Peter
Freund, Sid
Fuller, F. M., Jr.

Gaines, J. C.
Garner, C. F.
Garon, A. J., Jr.
Gibson, John F.
Gibson, John W.
Gilbert, Winfred H., Jr.
Gould, Charles S.
Gregg, Paul
Griffith, Richard D.
Gunter, Allen C.

Haegelin, J. A.
Halpenny, D. L.
Hamilton, Roger D.
Hanna, R. L.
Hardy, W. B., Jr.
Harris, Lewis P.
Harvey, Harry C.
Haschke, Marvin M.
Hastlings, S. J.
Henderson, G. T.
Hill, Lyle O.
Hillis, A. M.
Holton, Harry R.
Horn, W. E.
Houston, G. M.
Howell, D. E.
Hunt, W. T.
Hunter, Col. George W., III

Ivy, Edward E.

Jackson, Carl D.
Jasper, Frank P.
Jeffrey, F. I.
Johnson, H. S., Jr.
Johnston, H. G.
Jones, Warren F.
Jones, W. L., Jr.
Jonsson, F. M.
Julien, C. D.

Kennady, John W.
Kerley, B. J., Jr.
Kern, Curtis R.
King, Charles E.
King, Charles A., Jr.
Kirchhof, Gus
Kerley, Thomas J.
Knipling, E. F.
Kyd, Stirling

Lan, Simon G.
Landrum, John M.
Latimore, Jim
Lattimore, R. B.
Lee, Horace W.
Lindsay, Mrs. Joane
Linsley, R. B.
Lloyd, Edwin P.
Lloyd, Ralph R., Jr.

Magner, J. M.
Marriner, Donald
Marshall, R. P.
Martin, Dial F.
Martin, Leo A.
Maxwell, W. C.
McAlexander, D. J.
McCrory, S. J.
McCulloch, George
McGregor, Ted
McGregor, Walter S.
McKinney, Douglas R. McKinney
McKinney, Hulen
Meadows, C. M.
Mecom, W. H.
Melass, V. H.
Menzies, George C.
Merkl, Marvin E.
Millender, Nelson W.
Mistric, W. J., Jr.
Mitchell, N. W.
Moore, Joseph B.
Morris, J. S.
Morris, Ralph L.

Nailon, William T.
Neumayer, Miss Eleanor M.

O'Neal, Jim
Orr, Guy E.

Parencia, C. R., Jr.
Parker, Wm. B.
Paul, Rex
Peek, Carlton
Perlitz, W. J.
Persing, C. O.
Pfrimmer, Theodore R.
Philipkoski, Stan
Pierce, H. F.
Piesbergen, N.
Pippin, W. F.
Plant, E. K.
Plowman, W. W.
Pospichal, Alfred T.
Price, Manning A.

Radeleff, R. D.
Rainwater, Clyde F.
Randolph, Tom B.
Rapp, Frank
Reiser, Raymond
Reno, P. J.
Retzloff, A. F.
Richards, Rowland
Rider, F. L., Jr.
Ridgway, W. O.
Rigopi, Osvaldo
Riss, John S.
Robertson, Oris T.
Rogers, Jim
Rollins, E. M.

Sanchez, Louis O.
Scales, Arden L.
Scholtz, Lenwood L.
Schroeder, Erwin F., Jr.
Schwinn, David S.
Scoggin, John K.
Settle, Hubert H.
Sheridan, Edward S.
Silitzar, Guillermo Ramos
Simonds, James M.
Smith, Charles L.
Smith, Joe C.
Smith, W. R.
Snell, Arthur L.
Snipes, B. Thomas

Snook, Robert L.
Specht, Norman
Spencer, C. B.
Spicer, William J.
Starkey, Scott
Standish, W. L.
Stephenson, B. C.
Stiles, C. F.
Strandtmann, R. W.
Strong, Rudolph G.
Stroope, Don E.
Sudduth, W. R.
Swan, F. O.
Swoboda, Mike

Taylor, Wm. A.
Teer, Howard
Tennent, T. H.
Tennyson, H. W.
Tingdale, Donald M.
Todd, Frank E.
Torrey, John W.
Trolinger, Art

Vallier, Ernest E.
Vance, Arlo M.

Wagner, William E.
Wakeman, Robert I.
Walker, Wayne W.
Wallace, D. K.
Waters, Harold A.
Weaver, Nevin
Wells, R. W.
Wene, George
White, A. N.
White, J. P.
White, R. W.
Williams, P. L.
Williamson, Byron
Wipprecht, Read
Witman, E. D.
Woodbury, E. N.
Wooldridge, Bert
Worsham, W. J.
Wright, Fred N.

Young, Darrell M.

INTERDEPARTMENTAL COMMITTEE ON PEST CONTROL

Depts. of Agriculture—Interior—Army—Navy—Airforce and Federal Security Agency
January 30, 1952

Malathon—A coined name for the insecticidal chemical 0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate

The word "malathon" has been selected as a coined name for the insecticidal chemical 0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate and approved by the Interdepartmental Committee on Pest Control. The American Chemical Society is agreeable to its use. Malathon was formerly designated as S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate and also as Experimental Insecticide No. 4049.

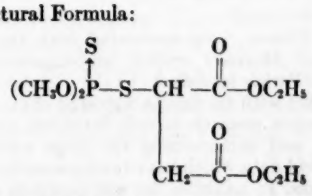
Malathon has been registered by the American Cyanamid Company as a trademark in the United States and in all important foreign countries. The company has taken steps to transfer the name to the supplementary list in the Trade-Mark Division from the list where it was originally registered for application as a trade-mark. The name "malathon" therefore is available for use as a common name for designating this chemical.

The name "malathon" applies to the pure chemical and a technical grade shall indicate the percentage of malathon present.

PHYSICAL AND CHEMICAL PROPERTIES.—Empirical Formula:

$$C_{10}H_{19}O_6PS_2.$$

Structural Formula:



A high boiling deep-brown to yellow liquid, some samples of which possess a characteristic odor. Boiling point 156–157° C. at 0.7 mm. with slight decomposition (99+%): melting point 2.85° C. (99+%): refractive index n_D^{25} 1.4985 (99+%): specific gravity 1.23 at 25° C. (90% technical): purity—technical grade 85–95 per cent. One gallon (90% technical) weighs approximately 10.25 pounds.

Solubility.—Slightly soluble in water (145 ppm.): miscible with many organic solvents including alcohols, esters, ketones, ethers, aromatic and alkalated aromatic hydrocarbons and vegetable oils. It has very limited solubility in certain paraffinic hydrocarbons without the use of a mutual solvent. Petroleum ether (30–60° C.) is soluble to the extent of 35% in malathon.

Compatibility.—Malathon rapidly hydrolyzes and loses its insecticidal efficiency under alkaline conditions. Mixtures with alkaline insecticides, fungicides, and inert materials should be avoided. Bordeaux mixture should not be used with malathon. Preliminary information indicates that both the wettable powder and the emulsifiable liquid may be used with the more commonly used insecticides and fungicides. In tests by entomologists during 1950 and 1951, formulations containing malathon were used in combinations with lead arsenate, parathion, wettable DDT, methoxychlor, TDE, ferbam, mineral oil, nabam, tri-basic copper sulfate, wettable sulfur, zineb, and ziram. No phytotoxic effects were reported with these combinations.

PHYTOTOXICITY.—The compound seems to be tolerated by a number of plants at the concentrations required for insect control. It is of interest to note that it is tolerated by McIntosh and related varieties of apples, which have been injured by higher dosages of certain organo-phosphorous compounds. Injury has been obtained on corn in the whorl stage and on Boston fern. Some stunting has occurred on cucumbers in the runner stage.

INSECTICIDAL PROPERTIES.—Field tests with malathon in 1950 and 1951 indicate that malathon may be useful for the control of certain pests of agricultural crops. Experimental work included spider mites on apple, pear, peach, prune, apricot, grape, walnuts, sugar beets, beans, cotton, and ornamentals; aphids on apple, cherry, pear, plum, broccoli, peas, peppers, potatoes, tomatoes, turnips, cotton, hops, wheat, and ornamentals; Mexican bean beetle; pear psylla. However, this work is still in the experimental stage and reference to it is not to be construed as a recommendation or justification for any of the uses indicated.

TOXICITY TO ANIMALS.—The toxicity to animals of purified malathon and of the technical of various grades and formulations has been investigated during 1950 and 1951. Animals appear to tolerate relatively large amounts of malathon regardless of the type of exposure. The acute oral LD_{50} for malathon 90% technical are as follows: In propylene glycol—albino rats 1156 mg./kg.; in corn oil—albino rats 479 mg./kg.; in corn oil-albino mice 885 mg./kg. Very large doses of malathon 90% technical (2460–6150 mg./kg.) are required to produce toxicity following single dermal applications to rabbits. Four or more daily dermal applications at doses approximating 1230 mg./kg. of malathon 90% technical are required to produce initial mortality in guinea pigs. Albino rats which have been receiving malathon 90% technical in basic laboratory diet at levels of 100, 1000, and 5000 ppm. have shown a steady weight gain and food consumption. The animals receiving 5000 ppm. have not gained as rapidly as the others, but are within normal limits. The prin-

cipal pharmacological action from malathon appears to be cholinesterase inhibition. Evidence available, to date, indicates that recovery from toxic doses is rapid. Atropine is antidotal.

ANALYTICAL METHODS.—Analytical methods are available for the determination of malathon in the technical grade and in formulations containing it. A sensitive analytical method is also available for determination of residues of malathon on fruits and vegetables. Copies of these methods may be obtained from the Agricultural Division, American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y.

Chloranil, a coined name for the fungicidal chemical tetrachloro-para-benzoquinone

The name "chloranil" was approved by the Interdepartmental Committee on Pest Control on December 5, 1951, for the pure chemical tetrachloro-para-benzoquinone. Approval of this name was requested by Dr. Dwight Powell, Chairman of the Committee on Fungicide Nomenclature, University of Illinois, Urbana. The name has actually been in use for a number of years and has appeared in text books. Approval of the name "chloranil" by the Interdepartmental Committee on Pest Control renders the name available for free use in designating the pure chemical tetrachloro-para-benzoquinone.

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BOOK NOTICE

A BRIEF HISTORY OF ENTOMOLOGY, by Herbert Osborn. 1952. The Spahr & Glenn Co., Columbus, Ohio. 1952. 6 by 9 inches, 303 pages, 58 plates. $4.50 postpaid.

This book supplements Dr. Osborn's "Fragments of Entomological History" the two volumes of which were published in 1937 and 1946 but does not in any sense replace them. The introduction outlines the origin of the science; succeeding sections deal with the origin of the science of entomology in its various ramifications—taxonomy, the economic phases of the study, the productive phases of the science as apiculture and sericulture and medical entomology, followed by discussions of the place of insects in a variety of other phases of their importance to man.

The gradual building up of the accumulated knowledge of insects into the Science of Entomology is treated in a fashion to interest the layman as well as the entomologist and a chapter is devoted to discussions of various aspects of modern development of the subject into the highly complicated profession it has become.

Perhaps more interesting to the reader, certainly so to the reviewer, is the introduction given to the entomologists of the past and the present. In this, many of those mentioned are associated with the phases of entomology in which they were most actively interested and in which their service to entomology and to mankind was most important.

The entomology of the world, so far as is practical in a work of the scope of the one under consideration, is such as to broaden the foundation of the students now preparing to enter the profession and to be, in addition, of great interest to the older members of the group who have not had opportunity to learn the facts in such a way as to impress himself with their collective importance.

Taxonomy receives consideration and serves to introduce most of the entomologists mentioned inasmuch as there are relatively few of them who were not attracted to the science as a whole through their early experience as collectors.

While the American entomologists are most prominent in the work our colleagues from the old world and other parts of America are by no means neglected.

The literature of entomology and those responsible for it, publication agencies as well as authors, if called to our attention.

If, as the poet says, the proper study of mankind is man, it would seem to follow that the proper study, or a proper study, of entomologists is entomologists, Dr. Osborn has contributed more to such study than any other man could. He has been a contemporary of practically all living entomologists and personally acquainted with most of them. And he has been the teacher of practically all of the entomologists of America, in the classroom, in the field and in other associations where they have been able to profit by the contact. He has had the interest to keep in touch with them and to continue the labor of keeping up to date on them.

In this book he shares with the rapidly increasing group his knowledge and personal memories and has supplemented this with reproductions of portraits which vastly increase the real and the sentimental value of the book to its readers.

Because of Dr. Osborn's personal knowledge and of his laboriously accumulated collection of portraits his book will always be unique and irreplaceable, and we come to realize that the present work is not merely a history of entomology but, in a very pertinent sense, a history of entomologists. The profession owes Dr. Osborn a debt which will never be completely acknowledged.

The Department of Agriculture conferred its Distinguished Service Award on Dr. Parker in Washington on May 15, 1952. He was one of seven scientists in the Department to receive this high honor. Dr. J. R. Parker of the Division of Cereal & Forage Insect Investigations of the Bureau, who has been in charge of its grasshopper research program with headquarters at Bozeman, Montana, for the past 20 years, is now giving full time to the preparation of important manuscripts on grasshoppers. Mr. Frank T. Cowan, long associated with the grasshopper and Mormon cricket investigations, succeeded Dr. Parker on July 1.

Dr. Parker with his fine background of experience in grasshopper research is well fitted for studying, analyzing, and summarizing the large amount of valuable field data which have been assembled under his direction. In addition, he will continue as consultant and advisor in connection with current grasshopper research programs.